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REPORT

OF THE

FORTY-THIRD MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

BRADFORD IN SEPTEMBER 1873.

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ERRATA IN REPORT FOR 1872.

Omitted from Index I.

Gaussian constants for the year 1829, report on the, or a theory of terrestrial magnetism founded on all available observations, 1.

Mascarene Islands, second supplementary report on the extinct birds of the, by A. Newton, 23.

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ERRATA IN THE PRESENT VOLUME.

In the Reports.

Page 369, line 22 from bottom, *for* Duncan *read* Dunkin.
382, ,, 8, *after* 11·09 *insert* per cent.
383, ,, 4, *for* Buchner *read* Buchner.
384, ,, 16, *for* Arnaud *read* Amand.
390, ,, 23 from bottom, *for* Persii *read* Persei.
396, ,, 13 from bottom, *after* Professor Baden Powell *insert a nota, thus* †.
399, ,, 20, *for* intrastellar *read* interstellar.

In the footnote of the Table of "Numbers of Meteors seen &c. in August 1872" (facing p. 395), observation of an aurora at Rothbury, *for* August 10th *read* August 9th.

In the Transactions of the Sections.

Page 43, fourth line from bottom, *for* Asturo *read* Arturo.
64, tenth line from bottom, *for* uranium oxide 1 $\overline{1}\frac{1}{4}$, $\dot{1}\frac{3}{4}$, &c. *read* uranium oxide $\overline{1\frac{1}{4}}$, $\dot{1}\frac{3}{4}$, &c.
70, line 11, *for* which it accom- *read* which it has accom-
173, lines 5 and 7, *for* Major Evan Smith *read* Major Euan Smith.

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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be pub-

lished after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

Associates for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one third of the Publication Price. Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the Arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

Class B. Temporary Members.

1. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.*

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections†, and of preparing Reports thereon,

* Passed by the General Committee, Edinburgh, 1871.

† *Notice to Contributors of Memoirs.*— Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be

and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first Meeting.

An Organizing Committee may also hold such preliminary Meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to settle the terms of their Report, after which their functions as an Organizing Committee shall cease.

Constitution of the Sectional Committees.*

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee †. The List of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the

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read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting*. It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before ...., addressed thus—"General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ......" If it should be inconvenient to the Author that his Paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note.

* Passed by the General Committee, Edinburgh, 1871.

† This and the following sentence were added by the General Committee, 1871.

Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printers, who are charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xix), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices Regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in Science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next meeting of the Association) forward to the General

Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, W. Spottiswoode, Esq., 50 Grosvenor Place, London, S.W., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, be commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant General Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S. F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, LL.D.
RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural-History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.

The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. .. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford.. The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford .. The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. .... The Lord Bishop of Oxford, D.D., F.R.S. .... The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford ...... Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. .. .. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. .... MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. .... The Lord Stanley, M.P., D.C.L., F.R.G.S. .... The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. .... Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S............ Sir Benjamin Heywood, Bart., F.R.S........................ .... Thomas Bazley, Esq., M.P.. James Aspinall Turner, Esq., M.P. .. .. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester. .... Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E.................. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, M.A., Esq. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge .... CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge .... The Very Rev. Harvey Goodwin, D.D., Dean of Ely .... The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. . ... Rev. J. Challis, M.A., F.R.S.... .... G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal............ Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. .. .. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S............. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. .... Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. .... Hugh Taylor, Esq., Chairman of the Coal Trade .... Isaac Lowthian Bell, Esq., Mayor of Newcastle .... Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers .... Rev. Temple Chevallier, B.D., F.R.A.S.................. .... William Fairbairn, Esq., LL.D., F.R.S..................................	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. .. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somersetshire .... The Most Noble the Marquis of Bath .... The Right Hon. Earl Nelson .... The Right Hon. Lord Portman .... The Very Reverend the Dean of Hereford .... The Venerable the Archdeacon of Bath .... W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. .... A. E. Way, Esq., M.P.. Francis H. Dickinson, Esq.. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire. The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Reverend the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. | F. Osler, Esq., F.R.S. J. T. Chance, Esq. | The Rev. Charles Evans, M.A.	William Mathews, Esq., jun., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonards, University of St. Andrews	J. Henderson, Esq., jun. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, C.B., Bart., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.

PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip De M. Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.SS.L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland. Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, M.P., C.B., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.SS.L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR. W. B. CARPENTER, LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex The Duke of Norfolk The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.R.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. J. Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, LL.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S. Sir John Hawkshaw, F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. Rev. Dr. Henry Rev. Dr. Robinson, F.R.S. Dr. Andrews, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Dr. T. Redfern. T. Sinclair, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place.	Presidents.	Secretaries.

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

1832. Oxford	Davies Gilbert, D.C L., F.R.S....	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S....	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.........	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

1835. Dublin	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R S....	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool ..	Sir D. Brewster, F.R.S...	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle..	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S.	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow .	Prof. Forbes, F.R.S.	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth .	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
1844. York	The Earl of Rosse, F.R.S...	Rev. Wm Hey, Prof. Stevelly.
1845. Cambridge..	The Very Rev. the Dean of Ely .	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford	Rev. Prof. Powell, M.A., F.R.S. .	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh..	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich......	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull	The Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ..	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S. ...	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin	Rev.T. R. Robinson,D.D.,F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.

Date and Place.	Presidents.	Secretaries.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen ...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford	Rev. B. Price, M.A., F.R.S.......	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester .	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge ..	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle..	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee......	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ..	Prof. J. Tyndall, LL.D., F.R.S...	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter ...	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh .	Prof. P. G. Tait, F.R.S.E.	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ..	W. De La Rue, D.C.L., F.R.S...	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S.....	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford . ..	John Dalton, D.C.L., F.R.S... ..	James F. W. Johnston.
1833. Cambridge..	John Dalton, D.C.L., F.R.S... .	Prof. Miller.
1834. Edinburgh ..	Dr. Hope....	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming..	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool..	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle..	Rev. William Whewell, F.R.S....	Prof. Miller, R. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Golding Bird, M.D., Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S. ..	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth..	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester.	John Dalton, D.C.L., F.R.S......	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. R. Playfair, E. Solly, T. H. Barker.
1845. Cambridge..	Rev. Prof. Cumming...............	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.

Date and Place.	Presidents.	Secretaries.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips. F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S..........	R. Hunt, G. Shaw.
1850. Edinburgh .	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S....	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S. .	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool ...	Prof. W. A. Miller, M.D, F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S. .	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen ...	Dr. Lyon Playfair, C.B., F.R.S. .	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester .	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge .	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle ..	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S. ..	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S. ...	Prof. A. Crum Brown, M.D., Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, M.D., A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S.......	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S.......	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge .	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh .	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*. R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool .	Rev. Prof. Sedgwick, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*. Captain H. M. Denham, R.N.

Date and Place.	Presidents.	Secretaries.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*. Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*. Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*. G.B.Greenough,F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth ..	H. T. De la Beche, F.R.S.	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge .	Rev. Prof. Sedgwick, M.A., F.R.S	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	Robert A. Austen, J. H. Norten, M.D., Prof. Oldham.—*Geography*. Dr. C. T. Beke.
1847. Oxford	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh *	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Professor Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S...	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.	Prof. Harkness, William Lawton.
1854. Liverpool . .	Prof. Edward Forbes, F.R.S. ..	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S.	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S.	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide ...	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen ..	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S., &c.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.......	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle ...	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.

* At a Meeting of the General Committee held in 1850, it was resolved "That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section," for Presidents and Secretaries of which see page xxxvi.

Date and Place.	Presidents.	Secretaries.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, J. McKenny Hughes, L. C. Miall.
1872. Brighton	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford	Rev. P. B. Duncan, F.G.S.	Rev. Prof. J. S. Henslow.
1833. Cambridge*	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin	Dr. Allman	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Brimingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow	Sir W. J. Hooker, LL.D	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York	Very Rev. The Dean of Manchester.	Prof Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. xxxvi.]

1848. Swansea	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.

* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xxxvi.

Date and Place.	Presidents.	Secretaries.
1851. Ipswich......	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S....	Robert Harrison, Dr. E. Lankester.
1854. Liverpool ...	Prof. Balfour, M.D., F.R.S......	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E. ...	William Keddie, Dr. Lankester.
1856. Cheltenham.	Thomas Bell, F.R.S., Pres.L.S....	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds.........	C. C. Babington, M.A., F.R.S...	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen ...	Sir W. Jardine, Bart., F.R.S.E..	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester..	Prof. C. C. Babington, F.R.S....	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge...	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle ...	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath	Dr. John E. Gray, F.R.S.	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S.	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY *.

1866. Nottingham.	Prof. Huxley, LL.D., F.R.S.—*Physiological Dep.* Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.* Alfred R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee	Prof. Sharpey, M.D., Sec. R.S.—*Dep. of Zool. and Bot.* George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S.—*Dep. of Physiology.* W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S.—*Dep. of Bot. and Zool.* C. Spence Bate, F.R.S.—*Dep. of Ethno.* E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, M.D., E. Ray Lankester, Professor Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. Anat. and Physiol.* Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.* J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.* Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.* Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir John Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.* Dr. Burdon Sanderson, F.R.S.—*Dep of Anthropol.* Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye Smith.

* At a Meeting of the General Committee in 1865, it was resolved:—"That the title of Section D be changed to Biology;" and "That for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' be substituted.

Date and Place.	Presidents.	Secretaries.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.* Prof. Rutherford, M.D.—*Dep. of Anthropol.* Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge...	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh...	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E. (UNTIL 1847.)—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool ...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle ...	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D................	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec.R.S. ...	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester.	Edward Holme, M.D., F.L.S. ..	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork.........	Sir James Pitcairn, M.D.	Dr. John Popham, Dr. R. S. Sargent.
1844. York........	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

SECTION E.—PHYSIOLOGY.

1845. Cambridge .	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S.........	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford* ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S. ...	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen ...	Prof. Sharpey, M.D., Sec.R.S. ...	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester.	Dr. John Davy, F.R.S.L. & E....	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge .	C. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle...	Prof. Rolleston, M.D., F.R.S. ...	Dr. D. Embleton, Dr. W. Turner.
1864. Bath........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm†.	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxxii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea ..	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh..	Vice-Admiral Sir A. Malcolm ...	Daniel Wilson.

* By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of "Section D—Zoology and Botany, including Physiology" (see p. xxxiv). The Section being then vacant was assigned in 1851 to Geography.

† *Vide* note on preceding page.

Date and Place.	Presidents.	Secretaries.
	SECTION E.—GEOGRAPHY AND ETHNOLOGY.	
1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S. ..	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin	Rev. Dr. J. Henthawn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen ...	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Professor Geddes, Dr. Norton Shaw.
1860. Oxford	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lempriere, Dr. Norton Shaw.
1861. Manchester.	John Crawfurd, F.R.S.	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge.	Francis Galton, F.R.S.	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle...	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir R. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee......	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.
	SECTION E (*continued*).—GEOGRAPHY.	
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool ..	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh.	Colonel Yule, C.B., F.R.G.S. ...	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton ...	Francis Galton, F.R.S.	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B....	H. W. Bates, A. Keith Johnston, Clements R. Markham.

STATISTICAL SCIENCE.

	COMMITTEE OF SCIENCES, VI.—STATISTICS.	
1833. Cambridge .	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh .	Sir Charles Lemon, Bart.	Dr. Cleland, C. Hope Maclean.
	SECTION F.—STATISTICS.	
1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Charles Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.

Date and Place.	Presidents.	Secretaries.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle...	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, F.R.S., M.P.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester.	G. W. Wood, M.P., F.L.S.	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P.	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge .	Rt. Hon. The Earl Fitzwilliam...	J. Fletcher, W. Cooke Tayler, LL.D.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S. ...	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh .	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich......	Sir John P. Boileau, Bart.	J. Fletcher, Prof Hancock.
1852. Belfast	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, Jun.
1853. Hull	James Heywood, M.P., F.R.S....	Edward Cheshire, William Newmarch.
1854. Liverpool ..	Thomas Tooke, F.R.S.	E Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow	R. Monckton Milnes, M.P.	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P. ...	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock Newmarch, W. M. Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds.........	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen ...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S.	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge..	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle ...	William Tite, M.P., F.R.S.	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath..........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...............	R. Birkin, Jun., Prof. Leone Levi, E. Macrory.
1867. Dundee......	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich ...	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.

Date and Place.	Presidents.	Secretaries.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A. ..	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves............	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P.	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P....	J. G. Fitch, Swire Smith.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S....	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool ...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle ...	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robert Stephenson.	W. Carpmael, William Hawkes, Thomas Webster.
1840. Glasgow ...	Sir John Robinson..................	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth...	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester .	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A......	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge ..	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S. .	William Betts, Jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh ..	Rev. Dr. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich......	William Cubitt, F.R.S...........	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S..	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool ...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, Jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, Jun., H. M. Jeffery.
1857. Dublin	The Right Hon. The Earl of Rosse, F.R.S.	Prof. Downing, W. T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds.........	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen ...	Rev. Prof. Willis, M.A., F.R.S. .	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester .	J. F. Bateman, C.E., F.R.S......	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge ..	William Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle ...	Rev. Prof. Willis, M.A., F.R.S. .	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S. ...	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.

Date and Place.	Presidents.	Secretaries.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S. .	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S....	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E...............	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, S. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.

List of Evening Lectures.

Date and Place.	Lecturer.	Subject of Discourse.
1842. Manchester .	Charles Vignoles, F.R.S.........	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison.................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge .	G. B. Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.........	Geology of Russia.
1846. Southampton	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schonbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S. ..	Shooting-stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S. ..	The Dodo (*Didus ineptus*).
1848. Swansea ..	John Percy, M.D., F.R.S.	Metallurgical operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S. ...	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S...............	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh.	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S...............	Extinct Birds of New Zealand.
1851. Ipswich......	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G. B. Airy, F.R.S., Astron. Roy.	Total Solar Eclipse of July 28, 1851.
1852. Belfast	Prof. G.G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.

Date and Place.	Lecturer.	Subject of Discourse.
1854. Liverpool ...	Prof. R. Owen, M.D., F.R.S....	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow......	Dr. W. B. Carpenter, F.R.S. ...	Characters of Species.
	Lieut.-Col. H. Rawlinson	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. W. Thomson, F.R.S.	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L. ..	Recent discoveries in Africa.
1858. Leeds........	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S. ...	The Fossil Mammalia of Australia.
1859. Aberdeen ..	Sir R. I. Murchison, D.C.L.	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S.	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S.... .	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester .	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Roy.	The late Eclipse of the Sun.
1862. Cambridge .	Prof. Tyndall, LL.D., F.R.S. ...	The Forms and Action of Water.
	Prof. Odling, F.R.S..	Organic Chemistry.
1863. Newcastle-on-Tyne.	Prof. Williamson, F.R.S.	The chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath	Prof Roscoe, F.R.S.	The Chemical Action of Light.
	Dr Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham.	William Huggins, F.R.S..........	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.........	Insular Floras.
1867. Dundee.....	Archibald Geikie, F.R.S.........	The Geological origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S...	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S......	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool ...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connexion with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.D., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford..............	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof Clerk Maxwell F.R.S......	Molecules.

Date and Place.	Lecturer.	Subject of Discourse.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich	Prof. Huxley, LL.D., F.R.S. ...	A piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S.	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	William Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S...	Fuel.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 14th August 1872 (commencement of BRIGHTON Meeting) to 17th September 1873 (BRADFORD).

RECEIPTS.

	£	s.	d.
To Balance brought from last Account	890	1	7
Received for Life Compositions at Brighton Meeting and since	400	0	0
,, Annual Subscriptions, ditto ditto	639	0	0
,, Associates' Tickets, ditto ditto	937	0	0
,, Ladies' Tickets, ditto ditto	911	0	0
,, Dividends on Stock	236	10	0
,, for Sale of Publications	39	13	0
	4053	4	7
	£4053	4	7

Examined and found correct.

J. GWYN JEFFREYS, JOHN PHILLIPS, JAMES J. SYLVESTER, } *Auditors.*

PAYMENTS.

	£	s.	d.	£	s.	d.
Paid Expenses of Brighton Meeting, also Sundry Printing, Binding, Advertising, and Incidental Petty Expenses				362	17	5
,, Printing, Engraving, &c. Report of 41st Meeting, Vol. XL. (Edinburgh)				452	19	11
,, Printing on account of Report of 42nd Meeting, Vol. XLI. (Brighton)				2	3	1
,, Salaries &c. (1 year)				480	0	0
,, Rent and Office Expenses (Albemarle Street)				104	5	0
,, On Account of Eclipse Expedition, 1871				41	3	4
,, Grants made at the Brighton Meeting, viz.—						
Sewage Committee	100	0	0			
Tidal Committee	400	0	0			
Zoological Record	100	0	0			
Chemistry Record	200	0	0			
Committee on Carboniferous Corals	25	0	0			
,, Kent's Cavern Exploration	150	0	0			
,, Fossil Elephants	25	0	0			
,, Wave-Lengths	150	0	0			
,, British Rainfall	100	0	0			
,, Essential Oils	30	0	0			
,, Mathematical Tables	100	0	0			
,, Gaussian Constants	10	0	0			
,, Sub-Wealden Explorations	25	0	0			
,, Underground Temperature	150	0	0			
,, Settle Cave Exploration	50	0	0			
,, Fossil Flora, Ireland	20	0	0			
,, Timber Denudation and Rainfall	20	0	0			
,, Luminous Meteors	30	0	0			
				1685	0	0
				3128	8	9
1873. Sept. 17. Balance at London and Westminster Bank	£897	12	10			
,, in hands of General Treasurer	27	3	0			
				924	15	10
				£4053	4	7

W. SPOTTISWOODE,
September 17, 1873.

Table showing the Attendance and Receipts

Date of Meeting.	Where held.	Presidents.	Old Life Members.	New Life Members.
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L. ...	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S. ..	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S....	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S. .	...	...
1838, Aug. 10 ..	Newcastle-on-Tyne ..	The Duke of Northumberland...	...	...
1839, Aug. 26 ...	Birmingham	The Rev. W. Vernon Harcourt .	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane ..	...	...
1841, July 20 ..	Plymouth	The Rev. W. Whewell, F.R.S...	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17 ..	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ..	York	The Rev. G. Peacock, D.D	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart .	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton...	149	3
1849, Sept. 12 ...	Birmingham	The Rev. T. R. Robinson, D.D..	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Esq., Astron. Royal .	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S. ...	164	10
1853, Sept. 3 ...	Hull	William Hopkins, Esq., F.R.S..	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S. ..	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D....	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds	Richard Owen, M.D., D.C.L. ...	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. The Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A.......	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Prof. Willis, M.A. ...	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne ..	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A....	287	40
1865, Sept. 6 ...	Birmingham	Prof. J. Phillips, M.A., LL.D....	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S. .	196	18
1869, Aug. 18 ...	Exeter.................	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D....	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D, F.R.S.		

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting.	Sums paid on Account of Grants for Scientific Purposes.
Old Annual Members.	New Annual Members.	Associates.	Ladies.	Foreigners.	Total.		
						£ s. d.	£ s. d.
...	...	...	...	...	353	....	....
...	...	...	...	...	...	....	....
...	...	...	...	...	900	....	....
...	...	...	...	...	1298	....	20 0 0
...	...	...	...	...	...	....	167 0 0
...	...	...	...	...	1350	....	434 14 0
...	...	...	...	...	1840	....	918 14 6
...	...	...	1100*	...	2400	....	956 12 2
...	...	...	...	34	1438	....	1595 11 0
...	...	...	...	40	1353	....	1546 16 4
46	317	...	60*	...	891	....	1235 10 11
75	376	33†	331*	28	1315	....	1449 17 8
71	185	...	160	...	...	....	1565 10 2
45	190	9†	260	...	...	....	981 12 8
94	22	407	172	35	1079	....	830 9 9
65	39	270	196	36	857	....	685 16 0
197	40	495	203	53	1260	....	208 5 4
54	25	376	197	15	929	707 0 0	275 1 8
93	33	447	237	22	1071	963 0 0	159 19 6
128	42	510	273	44	1241	1085 0 0	345 18 0
61	47	244	141	37	710	620 0 0	391 9 7
63	60	510	292	9	1108	1085 0 0	304 6 7
56	57	367	236	6	876	903 0 0	205 0 0
121	121	765	524	10	1802	1882 0 0	330 19 7
142	101	1094	543	26	2133	2311 0 0	480 16 4
104	48	412	346	9	1115	1098 0 0	734 13 9
156	120	900	569	26	2022	2015 0 0	507 15 3
111	91	710	509	13	1698	1931 0 0	618 18 2
125	179	1206	821	22	2564	2782 0 0	684 11 1
177	59	636	463	47	1689	1604 0 0	1241 7 0
184	125	1589	791	15	3139	3944 0 0	1111 5 10
150	57	433	242	25	1161	1089 0 0	1293 16 6
154	209	1704	1004	25	3335	3640 0 0	1608 3 10
182	103	1119	1058	13	2802	2965 0 0	1289 15 8
215	149	766	508	23	1997	2227 0 0	1591 7 10
218	105	960	771	11	2303	2469 0 0	1750 13 4
193	118	1163	771	7	2444	2613 0 0	1739 4 0
226	117	720	682	45‡	2004	2042 0 0	1940 0 0
229	107	678	600	17	1856	1931 0 0	1572 0 0
303	195	1103	910	14	2878	3096 0 0	1472 2 6
311	127	976	754	21	2463	2575 0 0	1285 0 0
280	80	937	912	43	2533	2649 0 0	1685 0 0
237	99	796	601	11	1983	2102 0 0	

* Ladies were not admitted by purchased Tickets until 1843.
† Tickets for admission to Sections only. ‡ Including Ladies.

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Professor Phillips, F.R.S.
Professor Sylvester, F.R.S.

Report of the Council for the Year 1872–73 *presented to the General Committee at Bradford, on Wednesday, September 17th,* 1873.

During the past year the Council have received Reports from the General Treasurer; and his account for the year will be presented to the General Committee this day.

The Council have had under their consideration the three resolutions which were referred to them by the General Committee at Brighton. They beg to report upon the action they have taken upon each case.

First Resolution.—"That the Council be requested to take such steps as they deem desirable to induce the Colonial Office to afford sufficient aid to the Observatory at Mauritius to enable an investigation of the Cyclones in the Pacific Ocean to be carried on there"*.

In accordance with this Resolution the following correspondence took place between Dr. Carpenter, the President of the Association, and the Right Honourable the Earl of Kimberley, Secretary of State for the Colonies:—

"British Association for the Advancement of Science,
22 Albemarle Street, W., December 20, 1872.

"MY LORD,—On behalf of the British Association, I have the honour to bring under your Lordship's notice the following statement respecting the position of the Observatory at the Mauritius:—

"The Mauritius Observatory is for the most part a Meteorological and Magnetical Observatory. As a Meteorological station, Mauritius is most important; and the present Director of the Observatory, Mr. Charles Meldrum, has taken advantage of his position to work out several important Meteorological problems as far as his means have allowed him.

"He has fostered the growth, if he did not originate, the Meteorological Society of Mauritius, of which he is the active Secretary, and his researches have been materially aided by these means.

"He has collated the logs of vessels crossing the Indian Ocean, extending over a period of between twenty and thirty years, and has derived from these some very important results. In the first place, it has been almost established by these observations that the behaviour of the barometer at the Mauritius affords an indication of storms taking place between that island and the Cape of Good Hope. By a study of these logs of ships he is also able to tell in what directions such storms travel, and thus he is able to give very valuable advice to ships' masters who should happen to be at the Mauritius. Moreover, Mr. Meldrum's recent observations tend to show that the cyclones in the Indian Ocean are periodical, and occur most frequently during those years when there are most sun-spots.

"In addition to this work, Mr. Meldrum's duties require him constantly to attend to the routine work of his observatory, to keep the time, &c. He is almost unprovided with assistants; and if he happens to be unwell the current work of the observatory is liable in a measure to be stopped. On account of overwork, Mr. Meldrum has lately been unwell for two months, although not so unwell as to put a stop to all his scientific labours.

* The resolution was adopted by the Council, with the following modification:—"That the Council take steps to induce the Colonial Office to afford sufficient pecuniary aid to the Observatory at Mauritius to enable an investigation of Cyclones to be carried on there."

"The importance of maintaining the sequence of the observations in the Mauritius Observatory, of further collating the logs of ships, and of continuing the inquiry into the periodicity of cyclones, has induced the British Association to urge upon your Lordship the necessity of affording additional assistance to Mr. Meldrum, to enable him to pursue these labours and perform his duties in a satisfactory manner.

"It may be assumed that such assistance, to be efficient, will cost about £300 a year beyond the present cost of the establishment; and if it is to be of value for the purpose of the investigation into the periodicity of cyclones, this additional allowance will have to be continued for a period of about ten years.

"I trust that the scientific importance of this subject will induce your Lordship to give this matter your favourable consideration, and to place Mr. Meldrum in a position to complete the inquiries he has commenced with so much success.

"I have the honour to be,
"My Lord,
"Your most obedient Servant,
(Signed) "WILLIAM B. CARPENTER,
President of the British Association."

"*The Right Hon. the Earl of Kimberley,
Secretary of State for Colonies.*"

"Downing Street,
19th December, 1872.

"SIR,—I am directed by the Earl of Kimberley to acknowledge the receipt of your letter of the 10th instant, urging, on behalf of the British Association, the necessity of affording additional assistance to Mr. Meldrum in his labours at the Mauritius Observatory.

"The Colonial Government is well aware of the value of the Meteorological researches now carried on at their Observatory by Mr. Meldrum; but the state of the finances of the Colony is such that *no* increase can be made to any of the Government establishments except on urgent grounds.

"The Secretary of State will, however, in deference to the wish expressed by the British Association, forward a copy of your letter to the Governor for his consideration and report.

"I am, Sir,
"Your obedient Servant,
(Signed) "R. M. MEADE."

"Downing Street,
18th February, 1873.

"SIR,—With reference to my letter of the 19th December last, I now forward to you, by the Earl of Kimberley's desire, the copy of a despatch which has been received from the Governor of Mauritius on the subject of affording assistance to Mr. Meldrum of the Mauritius Observatory. Lord Kimberley regrets that he cannot authorize any further charge for this service on the Colonial Revenue.

"I am, Sir,
"Your obedient Servant,
(Signed) "H. T. HOLLAND."

Sir A. H. Gordon to the Earl of Kimberley.

"Government House, Mahé, Seychelles,
15th January, 1873.

"My Lord,—I have had the honour to receive your Lordship's despatch (No. 302) of the 20th ultimo on the subject of the assistance to be afforded to Mr. Meldrum of the Mauritius Observatory.

"2. Some slight increase was made in this year's estimates to the amount voted for this purpose, but not to the extent proposed by the British Association.

"3. The whole subject is one in respect to which I should be glad to be informed of your Lordship's views and wishes.

"4. It is admitted, and indeed the increased grant is urged by the British Association on this ground, that the benefit of Mr. Meldrum's investigations is of general application, and that it is the advancement of science, and not any special interest of Mauritius itself that is concerned. Under these circumstances I confess that it seems to me hardly just that the revenue of Mauritius should bear the whole burden of these investigations, and that the Imperial Treasury, or, at all events, the Meteorological Society, might be fairly called upon to defray a part of the expenses incurred.

"I have &c.,
(Signed) "Arthur Gordon."

"*The Right Hon. the Earl of Kimberley, &c. &c.*"

In consequence of this communication the Council requested the President to urge upon the Lords Commissioners of Her Majesty's Treasury the desirability of affording such pecuniary aid to the Mauritius Observatory as would enable the Director to continue his observations on the periodicity of Cyclones; and an intimation has been received from Her Majesty's Government that an inquiry into the condition, size, and cost of the Establishment of the Mauritius is now being conducted by a Special Commission from England, pending which inquiry no increase of expenditure upon the Observatory can be sanctioned; but that when the results of this inquiry shall be made known the Secretary of State for the Colonies will direct the attention of the Governor to the subject.

Second Resolution.—"That, in the event of the Council having reason to believe that any changes affecting the acknowledged efficiency and scientific character of the botanical establishment at Kew are contemplated by the Government, the Council be requested to take such steps as in their judgment will be conducive to the interests of botanical science in this country."

The Council have not deemed it necessary to take any action upon this Resolution.

Third Resolution.—"That the Council be requested to take such steps as they may deem desirable to urge upon the Indian Government the preparation of a Photoheliograph and other instruments for solar observation, with the view of assisting in the observation of the Transit of Venus in 1874, and for the continuation of solar observations in India."

The Council communicated with His Grace the Duke of Argyll, the Secretary of State for India, upon the subject, with the result explained in the following correspondence:—

"British Association for the Advancement of Science,
22 Albemarle Street, W., November 27th, 1872.

"My Lord Duke,—On behalf of the British Association, I have the honour to urge upon your Grace's consideration the importance of making adequate preparation in India for the observation of the Transit of Venus in 1874, as well as of making provision for the continuation of solar observations in India, a matter to which the Council attach special importance.

"The observations ought to comprise both eye and photographic records; and the following instruments are specially recommended by the Council as those which it is desirable to procure at once. The photographic records should be made in the manner determined upon by the Astronomer Royal and by M. Otto Struve for the Russian Government—namely, by means of a Photoheliograph, on the principle of the instrument which has been worked at the Kew Observatory during ten years, but improved both in the optical and mechanical parts.

"For eye-observations it will be desirable to have a Telescope of the greatest excellence, of 6-inch aperture, mounted equatorially in the best manner, with a clockwork driver. It is also desirable to have a 4-inch telescope, mounted equatorially, and driven by clockwork.

"A transit instrument with clock, and one or two chronometers, and also an Altazimuth Instrument.

"As the 6-inch equatorial would be available afterwards for Sun Observations, it would be desirable to fit it with a Spectroscope of sufficient dispersive power to permit of the prominences being observed efficiently.

"The Council would recommend that the Heliograph should be worked continuously in India, inasmuch as such records are calculated to throw much light upon the causes of climatic changes, and it is impossible in any one locality to secure a continuous record of the sun's activity: observations of this nature are about to be proceeded with at the Royal Observatory, Greenwich; but past experience has shown that, on the average, half the days in the year are unproductive, and it is hoped that if India cooperates the gaps may be filled up.

"The Council of the Association trust that the importance of the subject will induce your Grace to give the matter a favourable consideration.

"I have the honour to be,
"My Lord Duke,
"Your most obedient Servant,
(Signed) "W. B. Carpenter,
President of the British Association."

"*His Grace The Duke of Argyll, K.G.,*
Secretary of State for India."

"India Office,
December 13th, 1872.

"Sir,—I am directed by the Secretary of State for India in Council to acknowledge the receipt of your letter of the 27th ultimo, expressing the desire of the Council of the British Association that provision may be made in India for observation in that country of the Transit of Venus in 1874, and for a continuation of solar observations in future.

"In reply, I am desired by the Duke of Argyll to state that His Grace has been in correspondence with the Astronomer Royal and the Government of India with reference to an observation in Northern India of the Transit of

Venus, and that a photoheliograph and other instruments are now in course of preparation for this object.

"With reference to the continuation of future solar observations in India, I am to add that there is a Government Astronomer in the Madras Presidency, and a Superintendent of the Colaba Observatory in the Bombay Presidency, besides Officers employed in the Survey Department in Bengal and the North-western Provinces, all of whom are engaged from time to time in recording observations of this nature.

"I am, Sir,
"Your obedient Servant,
(Signed) "HERMAN MERIVALE."

"*William B. Carpenter, Esq.,*
British Association,
22 *Albemarle Street, W.*"

"India Office,
February 28th, 1873.

"SIR,—With reference to my letter of the 13th of December last, relative to an observation in India of the Transit of the planet Venus in December 1874, I am directed to state, for the information of the Council of the British Association for the Advancement of Science, that the Secretary of State for India in Council, having reconsidered this matter, and looking to the number of existing burdens on the revenues of India, and to the fact that the selection of any station in that country was not originally contemplated for 'eye-observations' of the transit, has determined to sanction only the expenditure (£356 7*s.* 6*d.*) necessary for the purchase and packing of a Photoheliograph, and any further outlay that may be requisite for the adaptation of such instruments as may be now in India available for the purpose of the proposed observation.

"The Duke of Argyll in Council has been led to sanction thus much of the scheme proposed by Lieut.-Colonel Tennant, in consequence of the recommendation submitted by the Astronomer Royal in favour of the use of photography for an observation of the transit at some place in Northern India.

"I am, Sir,
"Your obedient Servant,
(Signed) "HERMAN MERIVALE."

"*William B. Carpenter, Esq.,*
British Association."

The General Committee will recollect that a Committee was appointed at Exeter in 1869, on the Laws Regulating the Flow and Action of Water holding Solid Matter in Suspension, consisting of Mr. J. Hawksley, Professor Rankine, Mr. R. A. Grantham, Sir A. S. Waugh, and Mr. T. Login, with authority to represent to the Government the desirability of undertaking experiments bearing on the subject. The Committee presented a Memorial to the Indian Government, who have recently intimated their intention of advancing a sum of £2000 to enable Mr. Login to carry on experiments.

The Council regret to have to announce the death of their Clerk, Mr. Askham, who was always most assiduous in his attention to his duties. They have appointed Mr. H. C. Stewardson in his place.

They recommend that a gratuity of £50 be given to Mr. Askham's Widow.

The Council have added the following list of names of gentlemen present at the last Meeting of the Association to the list of Corresponding Members:—

M. C. Bergeron. Lausanne.
Professor E. Croullebois. Paris.
Professor G. Devalque. Liège.
M. W. de Fonvielle. Paris.
Professor Paul Gervais. Paris.
Professor James Hall. Albany, New York.
Mr. J. E. Hilgard. Coast Survey, Washington.
M. Georges Lemoine. Paris.
Professor Victor von Richter. St. Petersburg.
Professor Carl Semper. Würtzburg.
Professor A. Wurtz. Paris.

The General Committee will remember that Belfast has already been selected as the place of meeting for next year. The Council have been informed that invitations to hold subsequent Meetings at Bristol and Glasgow will be presented to the General Committee.

Recommendations adopted by the General Committee at the Bradford Meeting in September 1873.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the Committee, consisting of Professor Cayley, Professor G. G. Stokes, Professor H. J. S. Smith, Professor Sir W. Thomson, and Mr. J. W. L. Glaisher (Secretary), on Mathematical Tables be reappointed, with a grant of £100 for the completion of the tabulation of the Elliptic Functions.

That the sum of £100 be granted to the Committee on Mathematical Tables towards the printing of the tables of the Elliptic Functions that have been calculated by the Committee.

That Mr. Glaisher, Colonel Strange, Professor Sir W. Thomson, Mr. Brooke, Mr. Walker, M. de Fonvielle, Professor Zenger, and Mr. Mann (Secretary), be a Committee for the purpose of investigating the efficacy of Lightning-conductors, giving suggestions for their improvement, and reporting upon any case in which a building has been injured by lightning, especially where such building was professedly protected by a lightning-conductor, and that the sum of £50 granted last year, but not expended, be regranted to the Committee.

That a Committee be appointed, consisting of Professor Balfour Stewart, Mr. Glaisher, and Mr. Lockyer, and that a grant of £100 be made to them in order to provide assistance to Mr. Meldrum in conducting meteorological researches in Mauritius.

That Professor Balfour Stewart and Mr. W. F. Barrett be a Committee for the purpose of investigating the magnetization of Iron, Nickel, and Cobalt, and that the sum of £20 be placed at their disposal for the purpose.

That the Committee for reporting on the Rainfall of the British Isles, consisting of Mr. Charles Brooke, Mr. Glaisher, Professor Phillips, Mr. G. J. Symons, Mr. J. F. Bateman, Mr. T. Hawksley, Mr. C. Tomlinson, and Mr. Rogers Field, be reappointed; that Mr. G. J. Symons be the Secretary, and that a grant of £100 be placed at their disposal for the purpose.

That the Committee, consisting of Mr. James Glaisher, Mr. R. P. Greg, Mr. Charles Brooke, Professor G. Forbes, and Professor A. S. Herschel, be

reappointed, and the sum of £30 be placed at their disposal for the purpose of showing the radiant-points of shooting-stars on graphical charts.

That the Committee on Thermo-Electricity, consisting of Professor Tait, Professor Tyndall, and Professor Balfour Stewart, be reappointed, and that the sum of £50 be placed at their disposal for the purpose.

That Professor A. W. Williamson, Professor Sir W. Thomson, Professor Clerk Maxwell, Professor G. C. Foster, Mr. Abel, Professor F. Jenkin, Mr. Siemens, and Mr. R. Sabine be reappointed a Committee for the purpose of testing the New Pyrometer of Mr. Siemens, and that the sum of £30 (which was granted last year and has lapsed) be regranted to the Committee.

That Professor Crum Brown, Mr. Dewar, Professor Tait, Professor Sir W. Thomson, and Dr. Gladstone be a Committee for the purpose of conducting investigations as to the determination of High Temperatures by various methods; that Mr. Dewar be the Secretary, and that the sum of £70 be placed at their disposal for the purpose.

That Professor Williamson, Professor Roscoe, and Professor Frankland be a Committee for the purpose of superintending the Monthly Records of the Progress of Chemistry published in the Journal of the Chemical Society, and that the sum of £100 be placed at their disposal for the purpose.

That Dr. Gladstone, Dr. C. R. A. Wright, and Mr. Chandler Roberts be reappointed a Committee for the purpose of investigating the chemical constitution and optical properties of essential oils; that Mr. Chandler Roberts be the Secretary; that the sum of £10 be placed at their disposal for the purpose; and that the subject of investigation be Isomeric Turpenes and their Derivatives.

That Dr. H. A. Armstrong and Dr. Thorpe be a Committee for the purpose of investigating Isomeric Cresols and their Derivatives; that Dr. Armstrong be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Professor A. S. Herschel and Mr. G. A. Lebour be a Committee for the purpose of conducting experiments on the conducting-power for Heat of certain rocks; that Professor Herschel be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Professor Phillips, Professor Harkness, Mr. Henry Woodward, Mr. James Thomson, Mr. John Brigg, and Mr. L. C. Miall be a Committee for the purpose of investigating and reporting upon the Labyrinthodonts of the Coal-measures; that Mr. L. C. Miall be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Bryce and Mr. William Jolly be a Committee for the purpose of collecting Fossils from localities of difficult access in the north-west of Scotland; that the specimens be deposited as arranged in the Resolution of last year; that Mr. William Jolly be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That the Rev. T. Wiltshire, Mr. J. Thomson, and Professor W. C. Williamson be a Committee for the purpose of continuing the investigation of Mountain Limestone Corals, and the preparation of plates for publication, and that the Committee be requested to direct their attention to the early publication of the results hitherto attained; that Mr. James Thomson be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. H. Willett, Mr. R. A. C. Godwin-Austen, W. Topley, Mr. Davidson, Mr. Prestwich, Professor Boyd Dawkins, and Mr. Henry Woodward be a Committee for the purpose of promoting the "Sub-Wealden Exploration;" that Mr. H. Willett be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Sir C. Lyell, Bart., Professor Phillips, Sir John Lubbock, Bart., Mr. J. Evans, Mr. E. Vivian, Mr. W. Pengelly, Mr. G. Busk, Mr. W. B. Dawkins, Mr. W. A. Sanford, and Mr. J. E. Lee be a Committee for the purpose of continuing the exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of £150 be placed at their disposal for the purpose.

That Professor Harkness, Mr. Prestwich, Professor Hughes, Rev. H. W. Crosskey, Messrs. C. J. Woodward, W. Boyd Dawkins, George Maw, L. C. Miall, G. H. Morton, and J. E. Lee be a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the more important of the Erratic Blocks of England and Wales, reporting other matters of interest connected with the same, and taking measures for their preservation; that the Rev. H. W. Crosskey be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Mr. Henry Woodward, Professor W. C. Williamson, Mr. F. W. Rudler, Mr. L. C. Miall, Mr. W. Topley, Mr. W. Whitaker, and Mr. G. A. Lebour be a Committee for the purpose of preparing a Record of Geological and Palæontological Literature; that Mr. Henry Woodward be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Sir John Lubbock, Bart., Professor Phillips, Professor Hughes, Messrs. W. Boyd Dawkins, L. C. Miall, and R. H. Tiddeman be a Committee for the purpose of assisting the exploration of the Victoria Cave, Settle; that R. H. Tiddeman be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Mr. Stainton, Sir John Lubbock, and Professor Newton be reappointed a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Mr. Gwyn Jeffreys, Mr. G. S. Brady, Mr. Robertson, and Mr. H. Brady be a Committee for the purpose of dredging off the coasts of Durham and North Yorkshire; that Mr. H. Brady be the Secretary, and that the sum of £30 be placed at their disposal for the purpose.

That Professor Balfour, Dr. McKendrick, and Mr. Dewar be a Committee for the purpose of carrying on investigations into the Physiological Action of Light; that Dr. McKendrick be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Dr. Pye-Smith, Dr. Brunton, and Mr. West be a Committee for the purpose of making physiological researches on the nature of intestinal secretion; that Dr. Brunton be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Dr. M. Foster, Mr. E. Ray Lankester, Dr. Anton Dohrn, and Mr. A. G. Dew-Smith be a Committee for determining the best methods of breeding the embryos of delicate marine organisms; that Dr. Anton Dohrn be the Secretary, and that the sum of £30 be placed at their disposal for the purpose.

That Colonel Lane Fox, Dr. Beddoe, Mr. Franks, Mr. Francis Galton, Mr. Edward Brabrook, Sir J. Lubbock, Bart., Sir Walter Elliot, Mr. Clements R. Markham, and Mr. E. B. Tylor be reappointed a Committee for the purpose of preparing and publishing brief forms of instruction for travellers, ethnologists, and other anthropological observers; that Colonel Lane Fox be the Secretary, and that the sum of £50 be placed at their disposal for the purpose, £25 being the renewal of the unexpended grant of last year.

That Lord Houghton, Professor Thorold Rogers, W. Newmarch, Professor Fawcett, M.P., Jacob Behrens, F. P. Fellows, R. H. Inglis Palgrave, Archi-

bald Hamilton, and S. Brown be a Committee for the purpose of inquiring into the economic effect of combinations of labourers or capitalists, and into the laws of Economic Science bearing on the principles on which they are founded; that Professor L. Levi be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That the Committee on instruments for measuring the speed of ships be reappointed; that it consist of the following Members:—Mr. W. Froude, Mr. F. J. Bramwell, Mr. A. E. Fletcher, Rev. E. L. Berthon, Mr. James R. Napier, Mr. C. W. Merrifield, Dr. C. W. Siemens, Mr. H. M. Brunel, Mr. W. Smith, Sir William Thomson, and Mr. J. N. Shoolbred; that Mr. J. N. Shoolbred be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That the sum of £50 be granted to Mr. Askham's widow (recommended by the Council).

Applications for Reports and Researches not involving Grants of Money.

That Professor Sylvester, Professor Cayley, Professor Hirst, Rev. Professor Bartholomew Price, Professor H. J. S. Smith, Dr. Spottiswoode, Mr. R. B. Hayward, Dr. Salmon, Rev. R. Townsend, Professor Fuller, Professor Kelland, Mr. J. M. Wilson, and Professor Clifford be reappointed a Committee (with power to add to their number) for the purpose of considering the possibility of improving the methods of instruction in elementary geometry; and that Professor Clifford be the Secretary.

That the Committee, consisting of Dr. Joule, Professor Sir W. Thomson, Professor Tait, Professor Balfour Stewart, and Professor J. Clerk Maxwell, be reappointed to effect the determination of the Mechanical Equivalent of Heat.

That the Committee, consisting of the following Members, with power to add to their number,—Professor Roscoe, Professor W. G. Adams, Professor Andrews, Professor Balfour, Mr. Baxendell, Mr. Bramwell, Professor A. Crum Brown, Mr. Buchan, Dr. Carpenter, Professor Core, Dr. De La Rue, Professor Thiselton Dyer, Sir Walter Elliot, Professor Flower, Professor G. C. Foster, Professor M. Foster, Colonel Lane Fox, Professor Geikie, Dr. J. H. Gladstone, Mr. Griffith, Rev. R. Harley, Dr. Hirst, Dr. Hooker, Dr. Huggins, Professor Huxley, Professor Fleeming Jenkin, Dr. Joule, Dr. Lankester, Mr. J. N. Lockyer, Professor Clerk Maxwell, Mr. D. Milne-Home, Dr. O'Callaghan, Professor Odling, Professor Ramsay, Dr. Spottiswoode, Mr. Stainton, Professor Balfour Stewart, Colonel Strange, Professor Tait, Mr. J. A. Tinné, Professor Allen Thomson, Professor Sir William Thomson, Professor Wyville Thomson, Professor Turner, Mr. G. V. Vernon, Professor A. W. Williamson, Professor Young, Professor Roscoe being the Secretary,—be reappointed—

1°, to consider and report on the best means of advancing science by Lectures, with authority to act, subject to the approval of the Council, in the course of the present year, if judged desirable.

2°, to consider and report whether any steps can be taken to render scientific organization more complete and effectual.

That the Eclipse Committee, consisting of the President and General Officers (with power to add to their number), be reappointed.

That the Committee on Tides, consisting of Professor Sir W. Thomson, Professor J. C. Adams, Mr. J. Oldham, Rear-Admiral Richards, General Strachey, Mr. W. Parkes, Mr. Webster, and Colonel Walker, be reappointed.

That the Committee on Underground Temperature, consisting of Professor

Everett (Secretary), Professor Sir W. Thomson, Sir Charles Lyell, Bart., Professor J. Clerk Maxwell, Professor Phillips, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. Glaisher, Rev. Dr. Graham, Mr. George Maw, Mr. Pengelly, Mr. S. J. Mackie, Professor Edward Hull, and Professor Ansted, be reappointed, with the addition of Dr. Clement Le Neve Foster.

That the Committee, consisting of Dr. Huggins, Mr. J. N. Lockyer, Dr. Reynolds, and Mr. Stoney, on Inverse Wave-lengths, be reappointed, and that Mr. Spottiswoode, Dr. De La Rue, and Dr. W. M. Watts be added to the Committee.

That the Committee, consisting of Professor Cayley, Mr. J. W. L. Glaisher, Dr. W. Pole, Mr. Merrifield, Professor Fuller, Mr. H. M. Brunel, and Professor W. K. Clifford, be reappointed to estimate the cost of constructing Mr. Babbage's Analytical Engine, and to consider the advisability of printing tables by its means.

That Mr. W. H. L. Russell be requested to continue his Report on recent progress in the Theory of Elliptic and Hyperelliptic Functions.

That Professor H. J. S. Smith, Professor Clifford, Professor W. G. Adams, Professor Balfour Stewart, Mr. J. G. Fitch, Mr. George Griffith, Mr. Marshall Watts, Professor Everett, Professor G. Carey Foster, and Mr. W. F. Barrett be a Committee (with power to add to their number) to consider and report on the extent and method of teaching Physics in Schools, and that Professor G. Carey Foster be the Secretary.

That Professor Sir W. Thomson, Professor Everett, Professor G. C. Foster, Professor J. Clerk Maxwell, Mr. G. J. Stoney, Professor Fleeming Jenkin, Dr. Siemens, Mr. Bramwell, Professor W. G. Adams, and Professor Balfour Stewart be a Committee for reporting on the Nomenclature of Dynamical and Electrical Units, and that Professor Everett be the Secretary.

That Professor Tait be requested to prepare a Report on Quaternions.

That Mr. Roberts, Dr. Mills, J. S. Sellon, Dr. Boycott, and Mr. Gadesden be a Committee for the purpose of inquiring into the method of making gold assays, and stating the results thereof; that Mr. W. C. Roberts be the Secretary.

That Dr. Bryce, Professor Sir W. Thomson, Mr. J. Brough, Mr. G. Forbes, Mr. D. Milne-Holme, and Mr. J. Thomson be a Committee for the purpose of continuing the Observations and Records of Earthquakes in Scotland, and that Dr. Bryce be the Secretary.

That the Rev. H. F. Barnes, Mr. Dresser, Mr. Harland, Mr. Harting, Professor Newton, and the Rev. Canon Tristram be reappointed a Committee for the purpose of inquiring into the possibility of establishing "a close time" for the protection of indigenous animals, and that Mr. Dresser be the Secretary.

That Professor Balfour, Dr. Cleghorn, Mr. Hutchinson, Mr. Buchan, and Mr. Sadler be reappointed a Committee for the purpose of taking observations on the effect of the denudation of timber on the rainfall of North Britain; that Mr. Hutchinson be the Secretary.

That Dr. Carpenter, Professor Allman, Professor Newton, and Mr. H. B. Brady be a Committee for the purpose of inquiring into and reporting upon the possibility of increasing the scientific usefulness of the Aquaria at Brighton and Sydenham; that Dr. Carpenter be the Secretary.

That the Metric Committee be reappointed, such Committee to consist of The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., The Right Hon. C. B. Adderley, M.P., Sir W. Armstrong, Mr. Samuel Brown, Dr. Farr, A. Hamilton, Professor Frankland, Professor Hennessy, Professor Leone Levi,

Mr. C. W. Siemens, Professor A. W. Williamson, Major-Gen. Strachey, and Dr. Roberts; that Professor Leone Levi be the Secretary.

That the Committee for the purpose of continuing the investigations on the Treatment and Utilization of Sewage be renewed, and that such Committee consist of Mr. R. B. Grantham, Professor Corfield, Mr. Bramwell, Dr. J. H. Gilbert, Mr. W. Hope, and Professor Williamson.

That Mr. J. R. Napier, Mr. F. J. Bramwell, Mr. C. W. Merrifield, Sir John Hawkshaw, Mr. T. Webster, Q.C., and Professor Osborne Reynolds be a Committee for the purpose of considering and reporting on British Measures in use for mechanical and other purposes, and that Mr. C. W. Merrifield be the Secretary.

That Mr. Francis Galton, Mr. C. W. Merrifield, Mr. W. Froude, and Professor Osborne Reynolds be a Committee for the purpose of obtaining a record of the varying amount of sea disturbance, and the measurement of waves near shore.

That Mr. F. J. Bramwell, Mr. Hawksley, Mr. Edward Easton, Sir William Armstrong, and Mr. W. Hope be a Committee to investigate and report upon the utilization and transmission of wind and water power; that Mr. W. Hope be the Secretary.

That Mr. H. Bessemer, Mr. F. J. Bramwell, Dr. Lyon Playfair, Dr. C. W. Siemens, and Mr. T. Webster, Q.C., be a Committee for the purpose of considering and reporting on the contributions to science due to inventors and invention in the industrial arts, and that Mr. T. Webster, Q.C., be the Secretary.

That Mr. W. H. Barlow, Mr. H. Bessemer, Mr. F. J. Bramwell, Captain Douglas Galton, Sir John Hawkshaw, Mr. C. W. Siemens, Professor Abel, and Mr. E. H. Carbutt be a Committee for the purpose of considering what steps can be taken in furtherance of the objects of the Address of the President of this Section [Mechanical] as to the use of steel for structural purposes, and that Mr. E. H. Carbutt be the Secretary.

Resolutions referred to the Council for consideration and action if it seem desirable.

That the Council be requested to take steps to bring the importance of the meteorological researches at Mauritius before the Government, in order that, when they become convinced of the value of these researches by the action of the Association, they may be induced to increase the assistance.

That the Council be requested to take such steps as they may consider desirable for the purpose of representing to Her Majesty's Government the importance of the scientific results to be obtained from Arctic Exploration.

That the Council be requested to consider the possibility and expediency of making arrangements for the constitution of an Annual Museum for the exhibition of specimens and apparatus on a similar footing to that of the Sections, and similarly provided with officers to superintend the arrangements.

That the Council of the British Association be requested to communicate with the authorities in charge of the St. Gothard Tunnel, with the view of obtaining permission for the Committee on Underground Temperature to take observations on temperature during the progress of the works.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

That Professor A. Schafarik's paper "On the visibility of the dark side of Venus" be printed *in extenso* among the Reports.

That Mr. Meldrum's paper "On a Periodicity of Cyclones and Rainfall in connexion with the Sun-spot Periodicity" be printed *in extenso* among the Reports.

That the Tables (extending to 3 or 4 pages) appended to Mr. Gwyn Jeffreys's paper "On Mediterranean Mollusca" be printed in the Report.

That Mr. Pengelly's paper, "The Flint and Chert Implements found in Kent's Cavern, Torquay, Devonshire," read in the department of Anthropology, be printed *in extenso* in the Annual Report.

That Mr. Firth's paper "On the Coal-cutting Machine" and Mr. Gott's paper (with the diagrams, on the understanding that the blocks be supplied) "On the Bradford Waterworks" be printed *in extenso* in the Annual Volume.

Resolution referred to the Parliamentary Committee.

That the Memorial from the Council of the Leeds Philosophical and Literary Society to the General Committee of the British Association be referred to the Parliamentary Committee.

[Copy.]

Memorial from the Council of the Leeds Philosophical and Literary Society to the General Committee of the British Association.

The Council of the Leeds Philosophical and Literary Society desrie to direct the attention of the General Committee of the British Association to a question of legislation capable of affecting prejudicially a number of Societies engaged in the promotion of science.

Since the British Association recognizes as one of its functions the vigilant observation through its Parliamentary Committee of current legislation affecting the interests of science, your memorialists have much confidence in bringing the subject before it.

The Rating Bill introduced by Government during the last Session of Parliament, proposed to withdraw from Scientific and Literary Societies the exemption from rating specially conferred upon them by an Act passed about thirty years ago.

The Institution which your memorialists represent, like many others, would have suffered seriously in its capability of maintaining a large Public Museum had this Bill become law.

After the discussion of the question in Parliament, your memorialists are convinced that no sufficient reason exists for thus abstracting from the funds of Scientific and Literary Societies a sum of money which is important to their efficiency, but too small to affect appreciably the question of the distribution of taxation. So many exemptions of religious and educational institutions were admitted by the amended Bill, that it could lay no claim to uniformity in its treatment of the subject of Rating.

Your memorialists respectfully invite the attention of the General Committee of the British Association to this subject, with the view of maintaining the present exemption, should further legislation be undertaken.

Signed,

By order of the Council of the Leeds Philosophical and Literary Society,

THOMAS WILSON, } *Hon. Secretaries.*
RICHARD REYNOLDS, }

Sept. 9th, 1873.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Bradford Meeting in September 1873. *The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.*

	£	s.	d.
Mathematics and Physics.			
*Cayley, Professor.—Mathematical Tables	100	0	0
Cayley, Professor.—Printing Mathematical Tables	100	0	0
Glaisher, Mr. J.—Efficacy of Lightning Conductors (renewed)	50	0	0
Balfour Stewart, Professor.—Mauritius Observatory	100	0	0
Balfour Stewart, Professor.—Magnetization of Iron	20	0	0
*Brooke, Mr.—British Rainfall	100	0	0
*Glaisher, Mr. J.—Luminous Meteors	30	0	0
*Tait, Professor.—Thermo-Electricity (renewed)	50	0	0
*Williamson, Prof. A. W.—Testing Siemens's New Pyrometer (renewed)	30	0	0
Chemistry.			
*Brown, Professor Crum.—High Temperature of Bodies (partly renewed)	70	0	0
*Williamson, Prof. A. W.—Records of the Progress of Chemistry (£100 renewed)	100	0	0
*Gladstone, Dr.—Chemical Constitution and Optical Properties of Essential Oils	10	0	0
Armstrong, Dr.—Isomeric Cresols and their Derivatives	20	0	0
Geology.			
Herschel, Professor.—Thermal Conducting-power of Rocks	10	0	0
Phillips, Professor.—Labyrinthodonts of the Coal-measures	10	0	0
*Bryce, Dr.—Collection of Fossils in the North-west of Scotland	10	0	0
*Wiltshire, Rev. T.—Investigation of Fossil Corals	25	0	0
*Willett, Mr. H.—The Sub-Wealden Exploration	25	0	0
*Lyell, Sir C., Bart.—Kent's Cavern Exploration	150	0	0
*Harkness, Professor.—Mapping Positions of Erratic Blocks and Boulders	10	0	0
Woodward, Mr. H.—Record of Geological and Palæontological Literature	100	0	0
*Lubbock, Sir J.—Exploration of Victoria Cave	50	0	0
Carried forward	£1170	0	0

* Reappointed.

Biology.

	£	s.	d.
Brought forward	£1170	0	0
*Lane Fox, Col. A.—Forms of Instruction for Travellers (£25 renewed)	50	0	0
*Stainton, Mr.—Record of the Progress of Zoology	100	0	0
Jeffreys, Mr. Gwyn.—Dredging off the Coasts of Yorkshire	30	0	0
Balfour, Professor.—Physiological Action of Light	20	0	0
Pye-Smith, Dr.—The Nature of Intestinal Secretion	20	0	0
Foster, Dr. M.—Methods of Breeding the Embryos of Delicate Marine Organisms	30	0	0

Statistics and Economic Science.

Houghton, Lord.—Economic Effects of Trades Unions	25	0	0

Mechanics.

*Froude, Mr. W.—Instruments for Measuring the Speed of Ships and Currents (renewed)	50	0	0
	1495	0	0
Askham's Widow, Mr	50	0	0
Total	£1545	0	0

* Reappointed.

The Annual Meeting in 1874.

The Meeting at Belfast will commence on Wednesday, August 19, 1874.

Place of Meeting in 1875.

The Annual Meeting of the Association in 1875 will be held at Bristol.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	0
Skeleton Maps	20	0	8
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Cooperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants......	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata ...	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas......1842	100	0	0
Geographical Distributions of Marine Zoology 1842	10	0	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Cooperation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph......	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall ...	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells......	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall......	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall......	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants..............	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants..............	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves ...	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

	£	s.	d.
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4
1858.			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859.			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1
1860.			
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	[illegible]	[illegible]	[illegible]

	£	s.	d.
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860 ...... £50 0 0; 1861 ...... £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0

	£	s.	d.
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	0
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c. Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyle and Methyle series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl series	25	0	0
Mercury and Bile	25	0	0
Organic remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0

	£	s.	d.
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Corals Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

General Meetings.

On Wednesday Evening, September 17, at 8 P.M., in St. George's Hall, Dr. W. B. Carpenter, LL.D., F.R.S., President, resigned the office of President to Professor Alexander W. Williamson, Ph.D., F.R.S., who took the Chair, and delivered an Address, for which see page lxx.

On Thursday Evening, September 18, at 8 P.M., a Soirée took place in St. George's Hall.

On Friday Evening, September 19, at 8.30 P.M., in St. George's Hall, Professor W. C. Williamson, F.R.S., delivered a Discourse on "Coal and Coal Plants."

On Saturday Evening, at 8 P.M., in St. George's Hall, Dr. C. W. Siemens, F.R.S., delivered a Discourse on "Fuel" to the Operative Classes of Bradford.

On Monday Evening, September 22, at 8.30 P.M., in St. George's Hall, Prof. Clerk Maxwell, F.R.S., delivered a Discourse on "Molecules."

On Tuesday Evening, September 23, at 8 P.M., a Soirée took place in the Mechanic's Institute.

On Wednesday, September 24, at 2.30 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Belfast*.

* The Meeting is appointed to take place on Wednesday, August 19, 1874.

ADDRESS

OF

ALEXANDER W. WILLIAMSON, Ph.D., F.R.S.,

PRESIDENT.

Ladies and Gentlemen,—

Instead of rising to address you on this occasion I had hoped to sit quietly amongst you, and to enjoy the intellectual treat of listening to the words of a man of whom England may well be proud—a man whose life has been spent in reading the great book of nature, for the purpose of enriching his fellow men with a knowledge of its truths—a man whose name is known and honoured in every corner of this planet to which a knowledge of science has penetrated—and, let me add, a man whose name will live in the grateful memory of mankind as long as the records of such noble work are preserved.

At the last Meeting of the Association I had the pleasure of proposing that Dr. Joule be elected President for the Bradford Meeting, and our Council succeeded in overcoming his reluctance and in persuading him to accept that office.

Nobly would Joule have discharged the duties of President had his bodily health been equal to the task; but it became apparent after a while that he could not rely upon sufficient strength to justify him in performing the duties of the Chair, and, in obedience to the orders of his physician, he placed his resignation in the hands of the Council about two months ago. When, under these circumstances, the Council did me the great honour of asking me to accept their nomination to the Presidentship, I felt that their request ought to have with me the weight of a command.

For a good many years past Chemistry has been growing at a more and more rapid rate, growing in the number and variety of facts which are added to its domain, and not less remarkably in the clearness and consistency of the ideas by which these facts are explained and systematized. The current literature of chemical research extends each year to the dimensions of a small library; and mere brief abstracts of the original papers published annually by the Chemical Society, partly aided by a grant from this Association, take up the chief part of a very stout volume. I could not, if I would, give you to-night even an outline of the chief newly discovered compounds and of the various changes which they undergo, describing each of them by its own name (often a very long one) and recording the specific properties which give to each substance its highest scientific interest. But I am sure that you

would not wish me to do so if I could; for we do not meet here to study chemistry; I conceive that we meet here for the purpose of considering what this wondrous activity in our science means, what is the use of it, and, true to our object as embodied in the name of this Association, to consider what we can do to promote the Advancement of Science. I propose to lay before you some facts bearing on each of these questions, and to submit to you some considerations respecting them.

In order to ascertain the meaning of the work which has been going on in chemistry, it will, I think, be desirable for us to consider the leading ideas which have been in the minds of chemists, and which guided their operations.

Now, since the father of modern chemistry, the great Dalton, gave to chemists a firm hold of the idea of Atoms, their labours have been continually guided by that fundamental idea, and have confirmed it by a knowledge of more and more facts, while at the same time steadily adding to our knowledge of the properties of atoms. Every chemist who is investigating a new compound takes for granted that it must consist of a great number of atom-clusters (called by him molecules), all of them alike, and each molecule consisting of a certain number of atoms of at least two kinds. One of his first endeavours is to ascertain how many atoms of each kind there are in each molecule of the compound. I must not attempt to describe to you the various kinds of experiment which he performs for the purpose of getting this information, how each experiment is carried out with the aid of delicate instruments and ingenious contrivances found by long experience to enable him to obtain the most trustworthy and accurate results; but I want to draw your attention to the reasoning by which he judges of the value of such experiments when they agree among themselves, and to the meaning which he attaches to their result.

If the result of his experiments does not nearly agree with any atomic formula (that is, if no conceivable cluster of atoms of the kinds known to be in the compound would on analysis give such results as those obtained), the chemist feels sure that his experiments must have been faulty: either the sample of substance which he worked upon contained foreign matter, or his analyses were not made with due care. He sets to work again, and goes on till he arrives at a result which is consistent with his knowledge of the combining-properties of atoms. It is hardly necessary to say that even the best experiment is liable to error, and that even a result obtained with the utmost care cannot be expected to afford more than an approximation to the truth. Every good analysis of a pure compound leads to results which approximate to those required by the Atomic Theory; and chemists trust so thoroughly to the truth of that guide, that they correct the results of such analysis by the aid of it.

The chemical idea of atoms serves for two purposes:—

1. It gives a clear and consistent explanation of an immense number of facts discovered by experiment, and enables us to compare them with one another and to classify them.

2. It leads to the anticipation of new facts, by suggesting new compounds which may be made; at the same time it teaches us that no compounds can exist with their constituents in any other than atomic proportions, and that experiments which imply the existence of any such compounds are faulty.

We have the testimony of the great Berzelius to the flood of light which the idea of atoms at once threw on the facts respecting combining proportions which had been accumulated before it was made known; and from that time

forward its value has rapidly increased as each succeeding year augmented the number of facts which it explained.

Allow me at this point of my narrative to pause for a moment in order to pay a tribute of respect and gratitude to the memory of one who has recently passed from among us, and who in the time of his full activity was a leader of the discoveries of new facts in the most difficult part of our science. Liebig has been generally known in this country through his writings on agricultural chemistry, through his justly popular letters on chemistry, and other writings, by means of which his brilliant intellect and ardent imagination stimulated men to think and to work. Among chemists he was famed for his numerous discoveries of new organic compounds, and their investigation by the aid of improved methods; but I believe that the greatest service which his genius rendered to science was the establishment of the chemical school of Giessen, the prototype of the numerous chemical schools for which Germany is now so justly celebrated. I think it is not too much to say that the Giessen laboratory, as it existed some thirty years ago, was the most efficient organization for the promotion of chemistry which had ever existed.

Picture to yourselves a little community of which each member was fired with enthusiasm for learning by the genius of the great master, and of which the best energies were concentrated on the one object of experimental investigation.

The students were for the most part men who had gone through a full curriculum of ordinary studies at some other University, and who were attracted from various parts of the world by the fame of this school of research.

Most of the leading workers of the next generation were pupils of Liebig; and many of them have established similar schools of research.

We must not, however, overlook the fact that Liebig's genius and enthusiasm would have been powerless in doing this admirable work, had not the rulers of his Grand-Duchy been enlightened enough to know that it was their duty to supply him with the material aids requisite for its successful accomplishment.

Numberless new compounds have been discovered under the guidance of the idea of atoms; and in proportion as our knowledge of substances and of their properties became more extensive, and our view of their characteristics more accurate and general, were we able to perceive the outlines of their natural arrangement, and to recognize the distinctive characteristics of various classes of substances. I wish I could have the pleasure of describing to you the origin and nature of some of these admirable discoveries, such as homologous series, types, radicals, &c.; but it is more to our purpose to consider the effect which they have had upon the idea of atoms, an idea which, still in its infancy, was plunged into the intellectual turmoil arising from a variety of novel and original theories suggested respectively by independent workers as best suited for the explanation of the particular phenomena to which their attention was mainly directed.

Each of these workers was inclined to attach quite sufficient importance to his own new idea, and to sacrifice for its sake any other one capable of interfering with its due development.

The father of the atomic theory was no more; and the little infant had no chance of life, unless from its own sterling merits it were found useful in the work still going on.

What then was the result? Did it perish like an ephemeral creation of human fancy? or did it survive and gain strength by the inquiries of those who questioned Nature and knew how to read her answers?

Although anticipating my answer to these questions, you will probably be surprised to hear the actual result which I have to record, a result so wonderful that the more I think of it the more I marvel at it. Not only did these various theories contain nothing at variance with the atomic theory; they were found to be natural and necessary developments of it, and to serve for its application to a variety of phenomena which were unknown to its founder.

Among the improvements of our knowledge of atoms which have taken place, I ought to mention the better evaluations of the relative weight of atoms of different kinds, which have been made since Dalton's time. More accurate experiments than those which were then on record have shown us that certain atoms are a little heavier or lighter than was then believed, and the work of perfecting our observations is constantly going on with the aid of better instruments and methods of operation. But, apart from these special corrections, a more sweeping change has taken place, not in consequence of more accurate experiments interpreted in the usual way, but in consequence of a more comprehensive view of the best experimental results which had been obtained, and a more consistent interpretation of them. Thus the atomic weight of carbon had been fixed at 6 by Dumas's admirable experiments; and it was quite conceivable that a still more perfect determination might slightly increase or diminish this number. But those who introduced the more sweeping change asserted in substance that two of these supposed atoms, whatever may be the precise weight of each, always are together and never separate from one another; and they accordingly applied the term atom to that indivisible mass of carbon weighing twice as much as a carbon atom had been supposed to weigh. So also with regard to other elements, it has been shown that many atoms are really twice as heavy as had been supposed, according to the original interpretation of the best experiments. This change was brought about by what I may be permitted to call the operation of stock-taking. Dalton first took stock of our quantitative facts in a business-like manner; but the amount and variety of our chemical stock increased so enormously after his time, that the second stock-taking absorbed the labours of several men for a good many years. They were men of different countries and very various turns of mind; but, as I mentioned just now, they found no other fundamental idea to work with than Dalton's; and the result of their labours has been to confirm the truth of that idea and to extend greatly its application.

One of the results of our endeavours to classify substances according to their natural resemblances has been the discovery of distinct family relationships among atoms, each family being distinguished by definite characteristics. Now, among the properties which thus characterize particular families of atoms, there is one of which the knowledge gradually worked out by the labours of an immense number of investigators must be admitted to constitute one of the most important additions ever made to our knowledge of these little masses.

I will endeavour to explain it to you by a simple example. An atom of chlorine is able to combine with one atom of hydrogen or one atom of potassium; but it cannot combine with two atoms. An atom of oxygen, on the other hand, can combine with two atoms of hydrogen or with two atoms of potassium, or with one atom of hydrogen and one of potassium; but we cannot get it in combination with one atom of hydrogen or of potassium solely.

Again, an atom of nitrogen is known in combination with three atoms of hydrogen; while an atom of carbon combines with four of hydrogen. Other

atoms are classified, from their resemblance to these respectively, as Monads, Dyads, Triads, Tetrads, &c.

The combining value which we thus recognize in the atoms of these several classes has led us naturally to a consideration of the order in which atoms are arranged in a molecule. Thus, in the compound of oxygen with hydrogen and potassium, each of these latter atoms is directly combined with the oxygen, and the atom of oxygen serves as a connecting link between them. Hydrogen and potassium have never been found capable of uniting directly with one another; but when both combined with one atom of oxygen they are in what may be called indirect combination with one another through the medium of that oxygen.

One of the great difficulties of chemistry some few years ago was to explain the constitution of isomeric compounds, those compounds whose molecules contain atoms of like kinds and in equal numbers, but which differ from one another in their properties. Thus a molecule of common ether contains four atoms of carbon, ten atoms of hydrogen, and one of oxygen. Butylic alcohol, a very different substance, has precisely the same composition. We now know that in the former the atom of oxygen is in the middle of a chain of carbon atoms, whereas in the latter it is at one end of that chain. You might fancy it impossible to decide upon any thing like consistent evidence such questions as this; but I can assure you that the atomic theory, as now used by chemists, leads frequently to conclusions of this kind, which are confirmed by independent observers, and command general assent. That these conclusions are, as far as they go, true descriptions of natural phenomena is shown by the fact that each of them serves in its turn as a stepping-stone to further discoveries.

One other extension of our knowledge of atoms I must briefly mention, one which has as yet received but little attention, yet which will, I venture to think, be found serviceable in the study of the forces which bring about chemical change.

The original view of the constitution of molecules was statical; and chemists only took cognizance of those changes of place among their atoms which result in the disappearance of the molecules employed, and the appearance of new molecules formed by their reaction on one another. Thus, when a solution of common salt (sodic chloride) is mixed with a solution of silver nitrate, it is well known that the metallic atoms in these respective compounds change places with one another, forming silver chloride and sodic nitrate; for the silver chloride soon settles to the bottom of the solution in the form of an insoluble powder, while the other product remains dissolved in the liquid. But as long as the solution of salt remained undecomposed, each little molecule in it was supposed to be chemically at rest. A particular atom of sodium which was combined with an atom of chlorine was supposed to remain steadily fixed to it. When this inactive solution was mixed with the similarly inactive solution of silver nitrate, the interchange of atoms known to take place between their respective molecules was nominally explained by the force of predisposing affinity. It was, in fact, supposed that the properties of the new compounds existed and produced effects before the compounds themselves had been formed.

I had occasion to point out a good many years ago that molecules which appear to be chemically at rest are reacting on one another when in suitable conditions, in the same kind of way as those which are manifestly in a state of chemical change—that, for instance, the molecules of liquid sodic chloride exchange sodium atoms with one another, forming new molecules of the same

compound undistinguishable from the first, so that, in an aggregate of like molecules, the apparent atomic rest is the result of the interchange of like atoms between contiguous molecules.

Such exchanges of atoms take place not only between molecules of identical composition, but also between contiguous molecules containing different elements. For instance, in a mixture of sodic chloride and potassic iodide an interchange of metallic atoms takes place, forming potassic chloride and sodic iodide. The result of the exchange in such a case is to form a couple of new molecules different from the original couple. But these products are subject to the same general law of atomic exchanges, and their action on one another reproduces a couple of molecules of the materials.

Thus a liquid mixture formed from two compounds, contains molecules of four kinds, which we may describe as the two materials and the two products. The materials are reacting on one another, forming the products; and these products are, in their turn, reacting on one another, reproducing the materials.

If one of the products of atomic exchange between two molecules is a solid while the other remains liquid (as when sodic chloride is mixed with silver nitrate), or if one is gaseous while the other remains liquid, so that the molecules of the one kind cannot react on those of the other kind and reproduce the materials, then the continued reaction of the materials on one another leads to their complete mutual decomposition. Such complete mutual decomposition of two salts takes place whenever they react on one another under such conditions that the products cannot react on one another and reproduce the materials; whereas partial decomposition takes place whenever the materials form a homogeneous mixture with the products.

Now, if in any such homogeneous mixture more exchanges of atoms take place between the materials than between the products, the number of molecules of the products is increased, because more of them are being made than unmade; and reciprocally, if more exchanges of atoms take place between the products than between the materials, the number of molecules of the materials is increased. The mixture remains of constant composition when there are in the unit of time as many decomposing changes as reproducing changes.

Suppose that we were to determine by experiment the proportion between the number of molecules of the materials, and the number of molecules of the products, in a mixture the composition of which remains constant, and that we found, for instance, twice as many of materials as of products; what would this mean? Why, if every two couples of materials only effect in the unit of time as many exchanges as every one couple of products, every couple of materials is only exchanging half as fast as every couple of products.

In fact you perceive that a determination of the proportion in which the substances are present in such a mixture will give us a measure of the relative velocities of those particular atomic motions; and we may thus express our result:—The force of chemical combination is inversely proportional to the number of atomic interchanges.

I cannot quit this part of our subject without alluding to the fact that some few chemists of such eminence as to be entitled to the most respectful attention, have of late years expressed an opinion that the idea of atoms is not necessary for the explanation of the changes in the chemical constitution of matter, and have sought as far as possible to exclude from their language any allusion to atoms.

It would be out of place on this occasion to enter into any discussion of the questions thus raised; but I think it right to point out:—

I. That these objectors have not shown us any inconsistency in the atomic theory, nor in the conclusions to which it leads.

II. That neither these nor any other philosophers have been able to explain the facts of chemistry on the assumption that there are no atoms, but that matter is infinitely divisible.

III. That when they interpret their analyses, these chemists allow themselves neither more nor less latitude than the Atomic Theory allows; in fact they are unconsciously guided by it.

These facts need no comment from me.

Our science grows by the acquisition of new facts which have an intelligible place among our ideas of the order of nature; but in proportion as more and more facts are arranged before us in their natural order, in proportion as our view of the order of nature becomes clearer and broader, we are able to observe and describe that order more fully and more accurately—in fact, to improve our ideas of the order of nature. These more extensive and more accurate ideas suggest new observations, and lead to the discovery of truths which would have found no place in the narrower and less accurate system. Take away from Chemistry the ideas which connect and explain the multifarious facts observed, and it is no longer a science; it is nothing more than a confused and useless heap of materials.

The answer to our question respecting the meaning of the earnest work which is going on in our science must, I think, now be plain to you. Chemists are examining the combining-properties of atoms, and getting clear ideas of the constitution of matter.

Admitting, then, for the present, that such is the meaning of chemical work, we have to consider the more important question of its use; and I think you will agree with me that, in order to judge soundly whether and in what manner such a pursuit is useful, we have to consider its effect upon Man. What habits of mind does it engender? What powers does it develope? Does it develope good and noble qualities and aspirations, and tend to make men more able and more anxious to do good to their fellow men? Or is it a mere idle amusement, bearing no permanent fruits of improvement?

You will, I think, answer these questions yourselves if I can succeed in describing to you some of the chief qualities which experience has shown to be requisite for the successful pursuit of Chemistry, and which are necessarily cultivated by those who qualify themselves for such a career.

One of the first requirements on the part of an investigator is accuracy in observing the phenomena with which he deals. He must not only see the precise particulars of a process as they present themselves to his observation; he must also observe the order in which these particular appearances present themselves under the conditions of each experiment. No less essential is accuracy of memory. An experimental inquirer must remember accurately a number of facts; and he needs to remember their mutual relations, so that one of them when present to his mind may recall those others which ought to be considered with it. In fact he cultivates the habit of remembering facts mainly by their place in nature. Accuracy in manual operations is required in all experimental inquiries; and many of them afford scope for very considerable skill and dexterity.

These elementary qualities are well known to be requisite for success in experimental science, and to be developed by careful practice of its methods; but some higher qualities are quite as necessary as these in all but the most rudimentary manipulations, and are developed in a remarkable degree by the higher work of science.

Thus it is of importance to notice that a singularly good training in the accurate use of words is afforded by experimental Chemistry. Every one who is about to enter on an inquiry, whether he be a first-year's student who wants to find the constituents of a common salt, or whether he be the most skilled and experienced of Chemists, seeks beforehand to get such information from the records of previous observations as may be most useful for his purpose. This information he obtains through the medium of words; and any failure on his part to understand the precise meaning of the words conveying the information requisite for his guidance is liable to lead him astray. Those elementary exercises in analytical chemistry, in which brief directions to the students alternate with their experiments and their reports of experiments made and conclusions drawn, afford a singularly effective training in the habit of attending accurately to the meaning of words used by others, and of selecting words capable of conveying without ambiguity the precise meaning intended. Any inaccuracy in the student's apprehension of the directions given, or in the selection of words to describe his observations and conclusions, is at once detected, when the result to which he ought to have arrived is known beforehand to the teacher.

Accuracy of reasoning is no less effectively promoted by the work of experimental chemistry. It is no small facility to us that the meaning of the words which we use to denote properties of matter and operations can be learnt by actual observation. Moreover each proposition comprised in chemical reasonings conveys some distinct statement susceptible of verification by similar means; and the validity of each conclusion can be tested, not only by examining whether or not it follows of necessity from true premisses, but also by subjecting it to the independent test of special experiment.

Chemists have frequent occasion to employ arguments which indicate a probability of some truth; and the anticipations based upon them serve as guides to experimental inquiry by suggesting crucial tests. But they distinguish most carefully such hypotheses from demonstrated facts.

Thus a pale green solution, stated to contain a pure metallic salt, is found to possess some properties which belong to Salts of Iron. Nothing else possesses these properties except Salts of Nickel; and they manifest a slight difference from Iron Salts in one of the properties observed.

The analyst could not see any appearance of that peculiarity which distinguishes Nickel Salts; so he concludes that he has probably got Iron in his solution, but almost certainly either Iron or Nickel. He then makes an experiment which will, he knows, give an entirely different result with Iron Salts and Nickel Salts; and he gets very distinctly the result which indicates Iron.

Having found in the green liquid properties which the presence of Iron could alone impart, he considers it highly probable that Iron is present. But he does not stop there; for, although the facts before him seem to admit of no other interpretation, he knows that, from insufficient knowledge or attention, mistakes are sometimes made in very simple matters. The analyst therefore tries as many other experiments as are known to distinguish Iron Salts from all others; and if any one of these leads distinctly to a result at variance with his provisional conclusion, he goes over the whole inquiry again, in order to find where his mistake was. Such inquiries are practised largely by students of chemistry, in order to fix in their minds, by frequent use, a knowledge of the fundamental properties of the common elements, in order to learn by practice the art of making experiments, and, above all, in order to acquire the habit of judging accurately of evidence in natural phenomena.

Such a student is often surprised at being told that it is not enough for him to conduct his experiments to such a point that every conclusion except one is contrary to the evidence before him—that he must then try every confirmatory test which he can of the substance believed to be present, and ascertain that the sample in his hands agrees, as far as he can see, in all properties with the known substance of which he believes it to be a specimen.

Those who tread the path of original inquiry, and add to human knowledge by their experiments, are bound to practise this habit with the most scrupulous fidelity and care, or many and grave would be the mistakes they would make.

Thus a Chemist thinks it probable that he might prepare some well-known organic body of the aromatic family by a new process. He sets to work and obtains a substance agreeing in appearance, in empirical composition, in molecular weight, and in many other properties with the compound which he had in view. He is, however, not satisfied that his product is a sample of that compound until he has examined carefully whether it possesses all the properties which are known to belong to the substance in question. And many a time is his caution rewarded by the discovery of some distinct difference of melting-point, or of crystalline form, &c., which proves that he has made a new compound isomeric with the one which he expected to make. It seemed probable, from the agreement of the two substances in many particulars, that they might be found to agree in all, and might be considered to be the same compound; but complete proof of that conclusion consists in showing that the new substance agrees with all that we know of the old one.

In the most various ways chemists seek to extend their knowledge of the uniformity of nature; and their reasonings by analogy from particulars to particulars suggest the working hypotheses which lead to new observations. Before, however, proceeding to test the truth of his hypothesis by experiment, the chemist passes in review, as well as he can, all the general knowledge which has any bearing on it, in order to find agreement or disagreement between his hypothesis and the ideas established by past experience. Sometimes he sees that his hypothesis is at variance with some general law in which he has full confidence, and he throws it aside as disproved by that law. On other occasions he finds that it follows of necessity from some known law; and he then proceeds to verify it by experiment, with a confident anticipation of the result. In many cases the hypothesis does not present sufficiently distinct agreement or disagreement with the ideas established by previous investigations to justify either the rejection of it or a confident belief in its truth; for it often happens that the results of experience of similar phenomena are not embodied in a sufficiently definite or trustworthy statement to have any other effect than that of giving probability or the contrary to the hypothesis.

Another habit of mind which is indispensable for success in experimental chemistry, and which is taught by the practice of its various operations, is that of truthfulness.

The very object of all our endeavours is to get true ideas of the natural processes of chemical action; for in proportion as our ideas are true do they give us the power of directing these processes. In fact our ideas are useful only so far as they are true; and he must indeed be blind to interest and to duty who could wish to swerve from the path of truth. But if any one were weak enough to make the attempt, he would find his way barred by innumerable obstacles.

Every addition to our science is a matter of immediate interest and im-

portance to those who are working in the same direction. They verify in various ways the statements of the first discoverer, and seldom fail to notice further particulars, and to correct any little errors of detail into which he may have fallen. They soon make it a stepping-stone to further discoveries. Any thing like wilful misrepresentation is inevitably detected and made known.

It must not, however, be supposed that the investigator drifts unconsciously into the habit of truthfulness for want of temptation to be untruthful, or even that error presents itself to his mind in a grotesque and repulsive garb, so as to enlist from the first his feelings against it; for I can assure you that the precise contrary of these things happens. Error comes before him usually in the very garb of truth; and his utmost skill and attention are needed to decide whether or not it is entitled to retain that garb.

You will easily see how this happens if you reflect that each working hypothesis employed by an investigator is an unproven proposition, which bears such resemblance to truth as to give rise to hopes that it may really be true. The investigator trusts it provisionally to the extent of trying one or more experiments, of which it claims to predict the specific result. Even though it guide him correctly for a while, he considers it still on trial until it has been tested by every process which ingenuity can suggest for the purpose of detecting a fault.

Most errors which an experimentalist has to do with are really imperfect truths, which have done good service in their time by guiding the course of discovery. The great object of scientific work is to replace these imperfect truths by more exact and comprehensive statements of the order of nature.

Whoever has once got knowledge from nature herself by truthful reasoning and experiment, must be dull indeed if he does not feel that he has acquired a new and noble power, and if he does not long to exercise it further, and make new conquests from the realm of darkness by the aid of known truths.

The habit of systematically searching for truth by the aid of known truths, and of testing the validity of each step by constant reference to nature, has now been practised for a sufficiently long time to enable us to judge of some of its results.

Every true idea of the order of nature is an instrument of thought. It can only be obtained by truthful investigation; and it can only be used effectively in obedience to the same laws. But the first idea which is formed of any thing occurring in nature affords only a partial representation of the actual reality, by recording what is seen of it from a particular point of view. By examining a thing from different points of view we get different ideas of it; and when we compare these ideas accurately with one another, recollecting how each one was obtained, we find that they really supplement each other.

We try to form in our minds a distinct image of a thing capable of producing these various appearances; and when we have succeeded in doing so, we look at it from the different points of view from which the natural object had been examined, and find that the ideas so obtained meet at the central image. It usually happens that an accurate examination of the mutual bearings of these ideas on the central image suggests additions to them, and correction of some particulars in them.

Thus it is that true ideas of a natural phenomenon confirm and strengthen

one another; and he who aids directly the development of one o them is sure to promote indirectly the consolidation of others.

Each onward step in the search for truth has made us stronger for the work; and when we look back upon what has been done by the efforts of so many workers simply but steadily directed by truth towards further truth, we see that they have achieved, for the benefit of the human race, the conquest of a systematic body of truths which encourages men to similar efforts while affording them the most effectual aid and guidance.

This lesson of the inherent vitality of truth, which is taught us so clearly by the history of our science, is well worthy of the consideration of those who, seeing that iniquity and falsehood so frequently triumph for a while in the struggle for existence, are inclined to take a desponding view of human affairs, and almost to despair of the ultimate predominance of truth and goodness. I believe it would be impossible at the present time to form an adequate idea of the vast consequences which will follow from the national adoption of systematic measures for allowing our knowledge of truth to develope itself freely, through the labours of those who are willing and able to devote themselves to its service, so as to strengthen more and more the belief and trust of mankind in its guidance, in small matters as well as in the highest and most important considerations.

I am desirous of describing briefly the more important of those measures; but first let me mention another habit of mind which naturally follows from the effective pursuit of truth,—a habit which might be described in general terms as the application to other matters of the truthfulness imparted by science.

The words which the great German poet put into the mouth of Mephistopheles when describing himself to Faust, afford perhaps the most concise and forcible statement of what we may call the anti-scientific spirit:—

„ Ich bin der Geist der stets verneint,
Dem alles, was entsteht, zuwider ist."

The true spirit of science is certainly affirmative, not negative; for, as I mentioned just now, its history teaches us that the development of our knowledge usually takes place through two or more simultaneous ideas of the same phenomenon, quite different from one another, both of which ultimately prove to be parts of some more general truth; so that a confident belief in one of those ideas does not involve or justify a denial of the others.

I could give you many remarkable illustrations of this law from among ideas familiar to Chemists. But I want you to consider with me its bearing on the habit of mind called toleration, of which the development in modern times is perhaps one of the most hopeful indications of moral improvement in man.

In working at our science we simply try to find out what is true; for although no usefulness is to be found at first in most of our results, we know well that every extension of our knowledge of truth is sure to prove useful in manifold ways. So regular an attendant is usefulness upon truth in our work, that we get accustomed to expect them always to go together, and to believe that there must be some amount of truth wherever there is manifest usefulness.

The history of human ideas, so far as it is written in the records of the progress of science, abounds with instances of men contributing powerfully to the development of important general ideas, by their accurate and conscientious experiments, while at the same time professing an actual disbelief in

those ideas. Those records must indeed have been a dead letter to any one who could stand carping at the intellectual crotchets of a good and honest worker, instead of giving him all brotherly help in furtherance of his work.

To one who knows the particulars of our science thoroughly, and who knows also what a variety of ideas have been resorted to in working out the whole body of truths of which the science is composed, there are few more impressive and elevating subjects of contemplation than the unity in the clear and bold outline of that noble structure.

I hope that you will not suppose, from my references to Chemistry as promoting the development of these habits and powers of mind, that I wish to claim for that particular branch of science any exclusive merit of the kind; for I can assure you that nothing can be further from my intention.

I conceived that you would wish me to speak of that department of science which I have had occasion to study more particularly; but much that I have said of it might be said with equal truth of other studies, while some of its merits may be claimed in a higher degree by other branches of science. On the other hand, those highest lessons which I have illustrated by chemistry are best learnt by those whose intellectual horizon includes other provinces of knowledge.

Chemistry presents peculiar advantages for educational purposes in the combination of breadth and accuracy in the training which it affords; and I am inclined to think that in this respect it is at present unequalled. There is reason to believe that it will play an important part in general education, and render valuable services to it in conjunction with other scientific and with literary studies.

I trust that the facts which I have submitted to your consideration may suffice to show you how fallacious is that materialistic idea of Physical Science which represents it as leading away from the study of man's noblest faculties, and from a sympathy with his most elevated aspirations, towards mere inanimate matter. The material work of science is directed by ideas towards the attainment of further ideas. Each step in science is an addition to our ideas, or an improvement of them. A science is but a body of ideas respecting the order of nature.

Each idea which forms part of Physical Science has been derived from observation of nature, and has been tested again and again in the most various ways by reference to nature; but this very soundness of our materials enables us to raise upon the rock of truth a loftier structure of ideas than could be erected on any other foundation by the aid of uncertain materials.

The study of science is the study of man's most accurate and perfect intellectual labours; and he who would know the powers of the human mind must go to science for his materials.

Like other powers of the mind, the imagination is powerfully exercised, and at the same time disciplined, by scientific work. Every investigator has frequent occasion to call forth in his mind a distinct image of something in nature which could produce the appearances which he witnesses, or to frame a proposition embodying some observed relation; and in each case the image or the proposition is required to be true to the materials from which it is formed. There is perhaps no more perfect elementary illustration of the accurate and useful employment of the imagination than the process of forming in the language of symbols, from concrete data, one of these admirable general propositions called equations; on the other hand, the contemplation of the order and harmony of nature as disclosed to us by science supplies the

imagination with materials of surpassing grandeur and brilliancy, while at the same time affording the widest scope for its efforts.

The foregoing considerations respecting the meaning and use of scientific work will, I trust, afford us aid in considering what measures ought to be taken in order to promote its advancement, and what we can do to further the adoption of such measures.

Like any other natural phenomenon, the growth of knowledge in the human mind is favoured and promoted by certain circumstances, impeded or arrested by others; and it is for us to ascertain from experience what those circumstances respectively are, and how the favourable ones can be best combined to the exclusion of the others.

The best and noblest things in this world are the result of gradual growth, by the free action of natural forces; and the proper function of legislation is to systematize the conditions most favourable to the free action which is desired.

I shall consider the words "Advancement of Science" as referring to the development and extension of our systematic knowledge of natural phenomena by investigation and research.

The first thing wanted for the work of advancing science is a supply of well-qualified workers. The second thing is to place and keep them under the conditions most favourable to their efficient activity. The most suitable men must be found while still young, and trained to the work. Now I know only one really effectual way of finding the youths who are best endowed by nature for the purpose; and that is to systematize and develope the natural conditions which accidentally concur in particular cases, and enable youths to rise from the crowd.

The first of these is that a young man gets a desire for knowledge by seeing the value and beauty of some which he has acquired. When he has got this desire, he exerts himself to increase his store; and every difficulty surmounted increases his love of the pursuit, and strengthens his determination to go on. His exertions are seen by some more experienced man, who helps him to place himself under circumstances favourable to further progress. He then has opportunities of seeing original inquiries conducted, perhaps even of aiding in them; and he longs to prove that he also can work out new truths, and make some permanent addition to human knowledge. If his circumstances enable him to prosecute such work, and he succeeds in making some new observations worthy of publication, he is at once known by them to the community of scientific men, and employed among them.

We want, then, a system which shall give to the young favourable opportunities of acquiring a clear and, as far as it goes, a thorough knowledge of some few truths of nature such as they can understand and enjoy—which shall afford opportunity of further and further instruction to those who have best profited by that which has been given to them, and are anxious to obtain more—which shall enable the best students to see what original investigation is, and, if possible, to assist in carrying out some research—and, finally, which shall supply to each student who has the power and the will to conduct researches, all material conditions which are requisite for the purpose.

But investigators, once found, ought to be placed in the circumstances most favourable to their efficient activity.

The first and most fundamental condition for this is, that their desire for the acquisition of knowledge be kept alive and fostered. They must not merely retain the hold which they have acquired on the general body of their

science; they ought to strengthen and extend that hold, by acquiring a more complete and accurate knowledge of its doctrines and methods; in a word, they ought to be more thorough students than during their state of preliminary training.

They must be able to live by their work, without diverting any of their energies to other pursuits; and they must feel security against want, in the event of illness or in their old age.

They must be supplied with intelligent and trained assistants to aid in the conduct of their researches, and whatever buildings, apparatus, and materials may be required for conducting those researches effectively.

The desired system must therefore provide arrangements favourable to the maintenance and development of the true student-spirit in investigators, while providing them with permanent means of subsistence, sufficient to enable them to feel secure and tranquil in working at science alone, yet not sufficient to neutralize their motives for exertion; and at the same time it must give them all external aids, in proportion to their wants and powers of making good use of them.

Now I propose to describe the outline of such a system, framed for the sole purpose of promoting research, and then to consider what other results would follow from its working.

If it should appear possible to establish a system for the efficient advancement of science, which would be productive of direct good to the community in other important ways, I think you will agree with me that we ought to do all that we can to promote its adoption.

Let the most intelligent and studious children from every primary school be sent, free of expense, to the most accessible secondary school for one year; let the best of these be selected and allowed to continue for a second year, and so on, until the *élite* of them have learnt all that is to be there learnt to advantage. Let the best pupils from the secondary schools be sent to a college of their own selection, and there subjected to a similar process of annual weeding; and, finally, let those who get satisfactorily to the end of a college curriculum be supplied with an allowance sufficient for their maintenance for a year, on condition of their devoting their undivided energies to research, under the inspection of competent college authorities, while allowed such aids and facilities as the college can supply, with the addition of money-grants for special purposes. Let all who do well during this first year be allowed similar advantages for a second, and even a third year.

Each young investigator thus trained must exert himself to obtain some appointment, which may enable him to do the most useful and creditable work of which he is capable, while combining the conditions most favourable to his own improvement.

Let there be in every college as many Professorships and Assistantships in each branch of science as are needed for the efficient conduct of the work there going on, and let every Professor and Assistant have such salary and such funds for apparatus &c. as may enable him to devote all his powers to the duties of his post, under conditions favourable to the success of these duties; but let each Professor receive also a proportion of the fees paid by his pupils, so that it may be his direct interest to do his work with the utmost attainable efficiency, and attract more pupils.

Let every college and school be governed by an independent body of men, striving to increase its usefulness and reputation, by sympathy with the labours of the working staff, by material aid to them when needed, and by getting the very best man they can from their own or any other college, to supply each vacancy as it arises.

In addition to colleges, which are and always have been the chief institutions for the advancement of learning, establishments for the observation of special phenomena are frequently needed, and will doubtless be found desirable in aid of a general system for the advancement of science.

Now, if a system fulfilling the conditions which I have thus briefly sketched out were once properly established on a sufficient scale, it ought to develop and improve itself by the very process of its working; and it behoves us, in judging of the system, to consider how such development and improvement would come about.

The thing most needed at the present time for the advancement of science is a supply of teachers devoted to that object—men so earnestly striving for more knowledge and better knowledge as to be model students, stimulating and encouraging those around them by their example as much as by their teaching. Young men do not prepare themselves in any numbers for such a career:—

I. Because the chief influences which surround them at school and at college are not calculated to awaken in them a desire to obtain excellence of such kind.

II. Because they could not expect by means of such qualities to reach a position which would afford a competent subsistence.

Let these conditions be reversed, to the extent that existing teachers have powerful inducements to make their students love the study of science for its own sake, with just confidence that they will be able to earn a livelihood if they succeed in qualifying themselves to advance science, and the whole thing is changed. The first batch of young investigators will be dispersed among schools and colleges according to their powers and acquirements, and will at once improve their influence upon the pupils, and enable them to send up a second batch better trained than the first. This improvement will go on increasing, if the natural forces which promote it are allowed free play; and the youth of each successive generation will have better and more frequent opportunities of awakening to a love of learning, better help and guidance in their efforts to acquire and use the glorious inheritance of knowledge which had been left them, better and more numerous living examples of men devoting their whole lives to the extension of the domain of truth, and seeking their highest reward in the consciousness that their exertions have benefited their fellow men, and are appreciated by them.

A young man who is duly qualified for the work of teaching the investigation of some particular branch of science, and who wishes to devote himself to it, will become a member of an association of men selected for their known devotion to learning, and for their ability to teach the methods of investigation in their respective subjects. Around this central group is arranged a frequently changing body of youths, who trust to them for encouragement and guidance in their respective studies.

Our young investigator finds it necessary to study again more carefully many parts of his subject, and to examine accurately the evidence of various conclusions which he had formerly adopted, in order that he may be able to lead the minds of his pupils by easy and natural yet secure steps to the discovery of the general truths which are within their reach. He goes over his branch of science again and again from the foundation upwards, striving each time to present its essential particulars more clearly and more forcibly, arranging them in the order best calculated to stimulate an inquiring mind to reflect upon their meaning, and to direct its efforts effectively to the discovery of the general ideas which are to be derived from them. He is en-

couraged in these efforts by the sympathy of his colleagues, and often aided by suggestions derived from their experience in teaching other branches of science, or by information respecting doctrines or methods which throw a light upon those of his own subject.

No known conditions are so well calculated to give a young investigator the closest and strongest grasp of his subject of which he is capable as those in which he is placed while thus earnestly teaching it in a college; and inasmuch as a thorough mastery of known truths is needed by every one who would work to advantage at the discovery of new truths of that kind, it will, in most cases, be an object of ambition to the ablest young investigators to get an opportunity of going through the work of teaching in a college, in order to improve themselves to the utmost for the work of original research. There is, however, another advantage to them in having such work to do; for the best way to ascertain at any one time what additions may be made to a science, is to examine the facts which have been discovered last, and to consider how far they confirm and extend the established ideas of the science, how far they militate against those ideas. An investigating teacher is constantly weaving new facts into the body of his science, and forming anticipations of new truths by considering the relation of these new facts to the old ones.

When our investigator has thus got a thorough mastery of his science and new ideas for its extension, he ought to have the opportunity of turning his improved powers to account by devoting more of his time to original research; in fact he ought to teach research by example more than hitherto, and less by elementary exercises upon known facts. If he has discharged the duties of his first post with manifest efficiency, he will be promoted, either in his own or some other college, to a chair affording more leisure and facility for original research by his own hands and by those of his assistants and pupils. Some investigators may find it desirable to give up after a while all teaching of previously published truths, and confine themselves to guiding the original researches of advanced pupils, while stimulating them by the example of their own discoveries. But most of them will probably prefer to do elementary teaching work from time to time, for the sake of the opportunity of going over the groundwork of their science, with a knowledge of the new facts and enlarged ideas recently established.

Now it must be observed that such a system as the above, once developed to its proper proportions, so as to send annually to secondary schools many thousands of poor children who would otherwise never enjoy such advantages, and so as to train to original investigation a corresponding proportion of them, would not only provide more young investigators than would be needed for systematic teaching functions, but would also give a partial training of the same kind to many whose abilities proved to be insufficient, or whose tastes were not congenial to such pursuit. Some would be tempted by an advantageous opening in an industrial pursuit or in the public service to break off their studies before completion, and others would find, after completing their training, a position of that kind more desirable or more attainable than a purely scientific appointment. Not only would much good of other kinds be accomplished by this circumstance, but we may say with confidence that the system could not work with full advantage for its own special purpose of promoting the advancement of science if it did not diffuse a knowledge of the truths and methods of science beyond the circle of teachers.

There is an urgent need of accurate scientific knowledge for the direction of manufacturing processes, and there could not be a greater mistake than to

suppose that such knowledge need not go beyond the elementary truths of science. In every branch of manufacture improvements are made from time to time, by the introduction of new or modified processes which had been discovered by means of investigations as arduous as those conducted for purely scientific purposes, and involving as great powers and accomplishments on the part of those who conducted them.

Any manufacturer of the present day who does not make efficient arrangements for gradually perfecting and improving his processes ought to make at once enough money to retire; for so many are moving onwards in this and other countries, that he would soon be left behind.

It would be well worth while to establish such a system of scientific education for the sake of training men to the habits of mind which are required for the improvement of the manufacturing arts; and I have no doubt that the expense of working the system would be repaid a hundred times over by the increase of wealth of the community; but I only mention this as a secondary advantage of national education.

A system of the kind could not expand to due dimensions, nor could it, once fully established, maintain itself in full activity, without intelligent sympathy from the community; and accordingly its more active-minded members must be taught some good examples of the processes and results of scientific inquiry, before they can be expected to take much interest in the results achieved by inquirers, and to do their share of the work requisite for the success of the system. I need hardly remind you that there are plenty of other strong reasons why some such knowledge of the truths of nature, and of the means by which they are found out, should be diffused as widely as possible throughout the community.

You perceive that in such educational system each teacher must trust to his own exertions for success and advancement; and he will do so if he is sure that his results will be known and compared impartially with those attained by others. Each governing body must duly maintain the efficiency of their school or college, if its support depend in some degree on the evidences of that efficiency; and they will try to improve their school if they know that every improvement will be seen and duly appreciated.

The keystone of the whole structure is the action of the State in distributing funds carefully among schools and colleges proportionally to the evidence of their doing good work, which could not be continued without such aid.

I am inclined to think that the State ought, as far as possible, to confine its educational grants to the purpose of maintaining and continuing good work which is actually being done, and rarely if ever to initiate educational experiments: first, because it is desirable to encourage private exertions and donations for the establishment of schools and colleges upon new systems, or in new localities, by giving the public full assurance that if any new institution establishes its right to existence, by doing good work for a while, it will not be allowed to die off for want of support; and, secondly, because the judicial impartiality required in the administration of public funds, on the basis of results of work, is hardly compatible with an advocacy of any particular means of attaining such results.

On the other hand, experience has shown that special endowments, which tie up funds in perpetuity for a definite purpose, commonly fail to attain their object under the altered circumstances which spring up in later generations, and not unfrequently detract from the efficiency of the institutions to which they are attached, by being used for objects other than those which it is their proper function to promote.

When there is felt to be a real want of any new institution for the promotion of learning, men are usually willing enough to devote time and money to the purpose of establishing it and giving it a fair trial. It is desirable that they should leave the State to judge of their experiment by its results, and to maintain it or not, according to the evidences of its usefulness. No institution ought, for its own sake, to have such permanent endowments as might deprive its members of motives for exertion.

The State could not, however, discharge these judicial functions without accurate and trustworthy evidence of the educational work done at the various schools and of its success. For this purpose a record must be kept by or under the direction of every teacher of the weekly progress of each pupil, showing what he has done and how he has done it. Official inspectors would have to see to these records being kept upon a uniform scale, so that their results might be comparable. The habit of keeping such records conduces powerfully to the efficiency of teachers; and, for the sake of the due development of the teaching system, it ought to prevail generally. Having such full and accurate means of knowing what opportunities of improvement pupils have enjoyed and what use they have made of those opportunities, Government ought to stimulate their exertions and test their progress by periodical examinations. It is of the utmost importance to allow any new and improved system of instruction to develope itself freely, by the exertions of those who are willing to undertake the labour and risk of trying it on a practical scale; and the pupils who acquire upon such new system a command of any branch of science, ought to have a fair opportunity of showing what they have achieved and how they have achieved it. An able and impartial examiner, knowing the new systems in use, will encourage each candidate to work out his results in the manner in which he has been taught to work out results of the kind.

Examinations thus impartially conducted with a view of testing the success of teachers in the work which they are endeavouring to do, have a far higher value, and consequent authority, than those which are conducted in ignorance or disregard of the process of training to which the candidates have been subjected; and we may safely say that the examination system will not attain its full usefulness until it is thus worked in intimate connexion with a system of teaching.

In order to give every one employed in the educational system the utmost interest in maintaining and increasing his efficiency, it is essential that a due measure of publicity be given to the chief results of their respective labours. Schools and colleges ought, to a considerable extent, to be supported by the fees paid by pupils for the instruction received; and every Professor being in part dependent upon the fees of his pupils will have a direct interest in attracting more pupils to his classes or laboratories. The fame of important original investigations of his own or his pupils, published in the scientific journals, is one of the natural means by which a distinguished Professor attracts disciples, and the success of his pupils in after life is another. His prospects of promotion will depend mainly on the opinion formed of his powers from such materials as these by the governing bodies of colleges and by the public; for if each college is dependent for success upon the efficiency of its teaching staff, its governing body must do their best to fill up every vacancy as it arises by the appointment of the ablest and most successful Professor whom they can get; and any college which does not succeed in obtaining the services of able men will soon lose reputation, and fall off in numbers.

There are, however, further advantages to the working of the system to be derived from full publicity of all its more important proceedings. It will supply materials for the formation of a sound public opinion respecting the proceedings of the authorities in their various spheres of action. A claim for money might be made upon Government by the rulers of some college upon inadequate grounds; or a just and proper claim of the kind might be disregarded by Government. Neither of these things will be likely to happen very often if the applications, together with the evidence bearing on them, are open to public scrutiny and criticism; and when they do occasionally happen, there will be a natural remedy for them.

If I have succeeded in making clear to you the leading principles of the plan to be adopted for the advancement of science, including, as it necessarily must do, national education generally, you will, I think, agree with me that, from the very magnitude and variety of the interests involved in its action, such system must of necessity be under the supreme control of Government. Science will never take its proper place among the chief elements of national greatness and advancement until it is acknowledged as such by that embodiment of the national will which we call the Government. Nor can the various institutions for its advancement develope duly their usefulness until the chaos in which they are now plunged gives place to such order as it is the proper function of Government to establish and maintain.

But Government has already taken, and is continuing to take, action in various matters affecting elementary popular education and higher scientific education, and it would be difficult to arrest such action, even if it were thought desirable to do so. The only practical question to be considered is how the action of Government can be systematized so as to give free play to the natural forces which have to do the work.

By establishing official examinations for appointments and for degrees, Government exerts a powerful influence on the teaching in schools and colleges, without taking cognizance, except in some few cases, of the systems of teaching which prevail in them. Again, they give grants of public money from time to time in aid of colleges or universities, or for the establishment of a high school under their own auspices. Sometimes they endow a Professorship. In taking each measure of the kind they are doubtless influenced by evidence that it is in itself a good thing, calculated to promote the advancement of learning. But a thing which is good in itself may produce evil effects in relation to others, or good effects incommensurate with its cost. Thus examinations afford most valuable aid to educational work when carried on in conjunction with earnest teachers; yet when established in the absence of a good system of education, they are liable to give rise to a one-sided training contrived with a special view of getting young men through the examinations. If no properly educated young men were found for a particular department of the public service, and an examination of all candidates for such appointments were to be established for the purpose of improving the system of training, candidates would consider their power of answering such questions as appeared likely to be set as the condition of their obtaining the appointments, and they would look out for men able and willing to train them to that particular work in as direct and effective a manner as possible. The demand for such instruction would soon be supplied. Some teachers would undertake to give instruction for the mere purpose of enabling candidates to get through the examination; and by the continued habit of such work would gradually come to look upon the examiners as malignant beings who keep youths out of office, and whose vigilance ought to be evaded by such means

as experience might show to be most effective for the purpose. Once this kind of direct examination-teaching has taken root, and is known to produce the desired effect of getting young men through the examinations, its existence encourages the tendency on the part of the candidates to look merely to the examination as the end and aim of their study; and a class of teachers is developed whose exertions are essentially antagonistic to those of the examiners.

There are, no doubt, teachers with a sufficiently clear apprehension of their duty, and sufficient authority, to convince some of the candidates that the proper object of their study should be to increase their power of usefulness in the career for which they are preparing themselves, by thoroughly mastering up to a prescribed point certain branches of knowledge; and that until they had honestly taken the means to do this and believed they had done it effectually, they ought not to go up for examination nor to wish to commence their career.

But it is desirable that all teachers be placed under such circumstances that it may become their interest as well as their duty to cooperate to the utmost of their powers in the object for which the examiners are working. For this purpose their records of the work done under their guidance by each pupil ought to be carefully inspected by the examiners before framing their questions, and ought to be accepted as affording the chief evidence of the respective merits of the pupils.

This is not the place for considering how the general funds for an effective system of national education can best be raised, nor how existing educational endowments can best be used in aid of those funds. It is well known that some colleges of Oxford and Cambridge are possessed of rich endowments, and that many distinguished members of those universities are desirous that the annual proceeds of those endowments should be distributed upon some system better calculated to promote the advancement of learning than that which generally prevails. Indeed we may confidently hope that, true to their glorious traditions, those colleges will be led, by the high-minded and enlightened counsels of their members, to rely upon improving usefulness in the advancement of learning as the only secure and worthy basis of their action in the use of their funds, so that they may take a leading part in such system of national education as may be moulded out of the present chaos.

But the foundations of a national system of education ought to be laid independently of the present arrangements at Oxford and Cambridge, for we may be sure that the more progress the system makes the more easy will become the necessary reforms in the older universities and colleges.

It is clearly undesirable that Government should longer delay obtaining such full and accurate knowledge of the existing national resources for educational purposes, and of the manner in which they are respectively utilized, as may enable them to judge of the comparative prospects of usefulness presented by the various modes of distributing educational grants. They ought to know what has been done and what is doing in the various public educational establishments before they can judge which of them would be likely to make the best use of a grant of public money.

We have official authority for expecting such impartial administration of educational grants; and it cannot be doubted that before long due means will be taken to supply the preliminary conditions.

You are no doubt aware that a Royal Commission was appointed some

time ago in consequence of representations made to Government by the British Association on this subject, and it is understood that their instructions are so framed as to direct their particular attention to the manner in which Government may best distribute educational grants. The Commission is moreover composed of most distinguished men, and we have every reason to anticipate from their labours a result worthy of the nation and of the momentous occasion.

In speaking of public educational establishments, I refer to those which by their constitution are devoted to the advancement of learning without pecuniary profit to their respective governing bodies. The annual expenditure requisite for keeping up a national system of popular education will necessarily be considerable from the first, and will become greater from year to year; but once Englishmen are fully alive to the paramount importance of the object, and see that its attainment is within their reach, we may be sure that its expense will be no impediment. England would not deserve to reap the glorious fruits of the harvest of knowledge if she grudged the necessary outlay for seed and tillage, were it even ten times greater than it will be. It is no use attempting to establish a national system on any other than a truly national basis. Private and corporate funds inevitably get diverted from popular use, after a few generations, to the use of the influential and rich. A national system must steadily keep in view the improvement of the poor, and distribute public funds each year in the manner best calculated to give to the youths of the poorest classes full opportunities of improvement proportional to their capacities, so that they may qualify themselves for the utmost useful ess to their country of which they are capable. The best possible security for the proper administration of the system will be found in the full and speedy publicity of all the particulars of its working.

It has been frequently remarked that a great proportion of English investigators are men of independent means, who not only seek no advancement as a reward of their labours, but often sacrifice those opportunities of improving their worldly position which their abilities and influence open up to them, for the sake of quietly advancing human knowledge. Rich and powerful men have very great temptations to turn away from science, so that those who devote their time and money to its service prove to us how true and pure a love of science exists in this country, and how Englishmen will cultivate it when it is in their power to do so.

Now and then a youth from the poorer classes is enabled by fortunate accidents and the aid of a friendly hand to climb to a position of scientific activity, and to give us, as Faraday did, a sample of the intellectual powers which lie fallow in the great mass of the people.

Now, the practical conclusion to which I want to lead you is, that it rests with you, who represent the national desire for the advancement of science, to take the only measures which can now be taken towards the establishment of a system of education worthy of this country and adapted to the requirements of science. In the present stage of the business the first thing to be done is to arouse public attention by all practicable means to the importance of the want, and to get people gradually to agree to some definite and practicable plan of action. You will, I think, find that the best way to promote such agreement is to make people consider the natural forces which have to be systematized by legislation, with a view of enabling them to work freely for the desired purpose. When the conditions essential to any national system come to be duly appreciated by those interested in the

cause of education, means will soon be found to carry out the necessary legislative enactments.

The highest offices in the State are on our present system filled by men who, whatever their political opinions and party ties, almost infallibly agree in their disinterested desire to signalize their respective terms of office by doing any good in their power. Convince them that a measure desired by the leaders of public opinion is in itself good and useful, and you are sure to carry it.

And, on the other hand, England is not wanting in men both able and willing to come forward as the champions of any great cause, and to devote their best powers to its service.

I may well say this at Bradford after the results achieved by your Member in the Elementary Education Act.

Objections will of course be raised to any system on the score of difficulty and expense, more especially to a complete and good system. Difficult of realization it certainly must be, for it will need the devoted and indefatigable exertions of many an able and high-minded man for many a long year. Only show how such exertions can be made to produce great and abiding results, and they will not be wanting. And as for expense, you will surely agree with me that the more money is distributed in such frugal and effective manner, the better for the real greatness of our country.

What nobler privilege is attached to the possession of money than that of doing good to our fellow men? and who would grudge giving freely from his surplus, or even depriving himself of some comforts, for the sake of preparing the rising generation for a life of the utmost usefulness and consequent happiness?

I confidently trust that the time will come when the chief item in the annual budget of the Chancellor of the Exchequer will be the vote for National Education. And when in some later age our nation shall have passed away, when a more true civilization has grown up and has formed new centres for its throbbing life, when there are but broken arches to tell of our bridges and crumbling ruins to mark the sites of our great cathedrals —then will the greatest and noblest of England's works stand more perfect and more beautiful than ever; then will some man survey the results of Old England's labours in the discovery of imperishable truths and laws of nature, and see that her energy and wealth were accompanied by some nobler attributes—that while Englishmen were strong and ambitious enough to grasp power, they were true enough to use it for its only worthy purpose, that of doing good to others.

I must not, however, trespass longer upon your time and your kind attention. My subject would carry me on, yet I must stop without having half done justice to it.

If I have succeeded in convincing you that a National system of Education is now necessary and possible, and in persuading you to do what you respectively can to prepare the way for it, I shall feel that the first step is made towards that great result.

REPORTS

ON

THE STATE OF SCIENCE.

Report of the Committee, consisting of Professor CAYLEY, *F.R.S.*, Professor STOKES, *F.R.S.*, Professor Sir W. THOMSON, *F.R.S.*, Professor H. J. S. SMITH, *F.R.S.*, *and* J. W. L. GLAISHER, *B.A.*, *F.R.A.S.* (Reporter), *on Mathematical Tables.*

§ 1. *General Statement of the Objects of the Committee.*

THE purposes for which the Committee was appointed were twofold, viz. (1) to form as complete a catalogue as possible of existing mathematical tables, and (2) to reprint or calculate tables which were necessary for the progress of the mathematical sciences.

These two objects, although so far connected, that it was absolutely essential before any tables were calculated or reprinted to be certain that such tables were not already in existence or easily accessible, were in other respects quite different; and the Committee have therefore decided to keep them distinct. The reasons in favour of the adoption of this course are obviously very strong, as a new table would be out of place in a Report which in other respects was merely a detailed catalogue. A further argument against the publication of the tables in the Reports of the Association, is the great objection to needlessly scattering tables. Tables of a kindred nature collected together, are of far more value than the same could be if dispersed in several volumes of a periodical; and if the tables of the Committee were published annually as calculated, it would happen not only that they would have to be sought in several volumes, and their utility in consequence considerably impaired, but sometimes even portions of the same table would be separated. The Committee have therefore considered that they would best carry out the second object for which they were appointed, by publishing their tables separately and independently of the Annual Reports of the Association.

The form chosen for this publication is a quarto of the same size as that of the Philosophical Transactions, this size being necessary for the uniformity of the tables, as a large page is required in order to contain the values of the function tabulated, together with its first, second, and third differences, which, when given, should range with the former on the same page. Before the

appointment of the Committee, certain tables of hyperbolic antilogarithms or exponentials (viz. e^x and e^{-x}) and of hyperbolic sines and cosines had been commenced by Mr. J. W. L. Glaisher; and these the Committee determined to print and stereotype on their completion. They are now in the press. A mass of calculations has been made for the tabulation of Bessel's functions, for real and imaginary values; and it is intended to complete these tables, and then to undertake calculations connected with the Elliptic Functions.

As yet no tables have been reprinted by the Committee; and it clearly would not be possible to decide which most required reproduction, until the Report was considerably advanced beyond its present stage.

All the tables printed by the Committee, whether calculated or reprinted, are to be stereotyped; and it is intended that they shall ultimately form a volume; but the tables relating to each function will be published and circulated separately as calculated, the stereotype-plates remaining in the possession of the Committee for future use.

The first object of the Committee was rendered necessary by the fact that the mathematical tables that have been formed, are scattered all over the world in the various mathematical and scientific journals, transactions of societies, &c., so that it is extremely difficult to ascertain what tables have been already calculated in any particular branch of science. Another reason is that tables formed for some particular purpose, and published under a title of special application, are often of equal importance in other investigations; so that great inconvenience is sometimes felt for the want of a table which already exists under another name and having reference to a different subject; or it may even be recalculated. The difficulty of knowing exactly the work already done in any subject is one which is common to all parts of science; but the inconvenience resulting from the nature of a work being obscured by its name is to a great extent peculiar to this subject, or at all events is more painfully felt in connexion with it. A familiar instance of a function occurring in several distinct subjects is the integral $\int_x^{\infty} e^{-x^2}dx$, which is of importance in the determination of the probable error in the method of Least Squares, Astronomical Refractions, and the theory of Heat; and good instances of the manner in which the nature of a table can be obscured by its name are afforded by nautical collections, where under such headings as "Table to find the latitude by double altitudes of the sun and the elapsed time," or "Table of logarithmic risings," &c., are given log cosecants, log versed sines, &c. A catalogue, therefore, in which the tables were carefully described *from their contents* seemed very desirable; and this the Committee hope to be able to accomplish by their Reports.

It is intended to include all *numerical* tables that can be regarded as belonging to mathematical science, or which are of interest in connexion therewith; but none will be noticed in which the tabular results or data are derived from observation or experiment, or merely concern special subjects that are not generally classed under the head of mathematics. Thus the great majority of astronomical tables, including catalogues of stars, tables of refraction, tables depending on the figure of the earth, &c., will be excluded, as the data for the formation of such tables are derived from observation. The same remark applies to all chemical tables, tables of specific gravity, of weights and measures, for the determination of the longitude at sea, mortality tables, &c. Life-assurance and annuity tables, and all commercial tables will also be excluded. With regard to these last, however, although all tables such as ready reckoners and common interest tables will in general be omitted,

any one that is of value in relation to mathematics as a science will be included, although it may have been calculated for merely commercial purposes and published under a name that would apparently exclude it from this Report. Many tables of compound interest are valuable when viewed as tables of powers; and many navigation tables calculated merely for the use of the sailor, and published under titles that would imply that they were of a merely technical character, are in reality trigonometrical tables under a disguised form.

From the above remarks it will be found in most cases very easy to decide whether a table is included in the scope of this Report or not. A few of course come on the boundary; and then there is some little difficulty in drawing the line fairly. Of this kind are tables for the expression of hours and minutes as decimals of a day, &c.; most of these it has been thought better to include.

It was necessary as a preliminary to form a classification of mathematical (numerical) tables; and the following classification was drawn up by Prof. Cayley and adopted by the Committee.

A. Auxiliary for non-logarithmic computations.
  1. Multiplication.
  2. Quarter-squares.
  3. Squares, cubes, and higher powers, and reciprocals.

B. Logarithmic and circular.
  4. Logarithms (Briggian) and antilogarithms (do); addition and subtraction logarithms, &c.
  5. Circular functions (sines, cosines, &c.), natural, and lengths of circular arcs.
  6. Circular functions (sines, cosines, &c.), logarithmic.

C. Exponential.
  7. Hyperbolic logarithms.
  8. Do. antilogarithms (e^x) and h. l tan $(45^\circ+\frac{1}{2}\phi)$, and hyperbolic sines, cosines, &c., natural and logarithmic.

D. Algebraic constants.
  9. Accurate integer or fractional values. Bernoulli's Nos., $\Delta^n 0^m$, &c. Binomial coefficients.
  10. Decimal values auxiliary to the calculation of series.

E. 11. Transcendental constants, e, π, γ, &c., and their powers and functions.

F. Arithmological.
  12. Divisors and prime numbers. Prime roots. The Canon arithmeticus &c.
  13. The Pellian equation.
  14. Partitions.
  15. Quadratic forms a^2+b^2, &c., and partition of numbers into squares, cubes, and biquadrates.
  16. Binary, ternary, &c. quadratic and higher forms.
  17. Complex theories.

G. Transcendental functions.
  18. Elliptic.
  19. Gamma.
  20. Sine-integral, cosine-integral, and exponential-integral.
  21. Bessel's and allied functions.
  22. Planetary coefficients for given $\frac{a}{a'}$.
  23. Logarithmic transcendental.
  24. Miscellaneous.

Several of these classes need some little explanation. Thus D 9 and 10 are intended to include the same class of constants, the only difference being that in 9 accurate values are given, while in 10 they are only approximate; thus, for example, the accurate Bernoulli's numbers as vulgar fractions, and the decimal values of the same to (say) ten places are placed in different classes, as the former are of theoretical interest, while the latter are only of use in calculation. It is not necessary to enter into further detail with respect to the classification, as in point of fact it is only very partially followed in the Report; the final index, however, will be constructed as much in accordance with it as possible.

The only perfect method by which all the tables on the above subjects could be found with any certainty, is to examine all the volumes of the mathematical and philosophical journals and transactions, given in the list prefixed to the Royal Society's Catalogue of Scientific papers—a most laborious work, as it requires every page in all these periodicals to be looked at, and any numerical tables noted and subsequently examined, while if included in the scope of the Committee's work they must further be described. The mere turning over the pages of several thousand volumes is a work of some labour, and the completion of the Report must occupy the Committee for several years. The work is also of such a nature that it would not be possible to obtain even an approach to completeness in any one class till very considerable progress had been made with the preliminary examination.

This, however, is not the case to any great extent with the groups A and B, or with C 7 or the first part of F 12, as tables in these classes are generally to be found in separate books, and not in the memoirs of societies, or journals. It was possible, therefore, to make progress in the above classes immediately; and the portion of the Report now presented to the Association, practically contains a catalogue of tables which form separate books. The three broad divisions into which mathematical tables divide themselves *practically* are found to be:—

I. Subsidiary tables, which are rather of value as a means of performing calculations than of interest in themselves: *e. g.* multiplication tables, logarithms, &c. They generally form separate books.

II. Tables of continuous functions, generally definite integrals.

III. Tables in the theory of numbers.

Divisions II. and III. contain *conclusive* (in opposition to *subsidiary*) tables.

A fuller description of the contents &c. of Division I. will be found in § 2. It is hoped next year to report on Division II., and the next year on Division III. It will be necessary afterwards to add supplements to different classes, and notably to the present portion of the Report, which has no claim at all to be regarded as complete, but is published on the distinct understanding that it is by no means exhaustive with regard to the subjects treated in it; a supplementary Report on the same subject will be subsequently added; and it is hoped that thus it will be rendered complete (see § 2).

§ 2. *General Introduction to the present Report, and Explanation of its Arrangement and Use.*

Art. 1. The present Report is intended to include all *general* tables, viz. tables that are of general application in all branches of mathematics, and are therefore useful wherever calculations have to be performed. The most simple instances are multiplication tables, common logarithms of numbers,

and trigonometrical functions, which form the basis of, and are the means by which all other calculations are made. Regarded from this point of view, this division may be said to contain auxiliary or subsidiary tables, viz. such as are not *per se* of any very great intrinsic interest (multiplication tables are a good instance), but which are nevertheless of such paramount importance that, without their aid, the calculation of other tables would be too laborious to be practicable. As before remarked, one reason why these tables may well form a division by themselves is, that, being intended for calculations of all kinds, they are usually published separately, and have not to be sought among the transactions of societies and other periodicals. The number of tables in this class is of course many times greater than are all the other classes put together; but then, on the other hand, they admit of more brief description, as scarcely any explanation is needed of the functions tabulated, or of the purposes for which the calculation or publication was undertaken. In the present Report not above five or six tables printed in periodical publications are noticed; while it is probable that in the Reports on the other classes there will not be a much greater number that will have appeared as separate and independent books.

Art. 2. The object of the Report is to enable any one by means of it to find out with ease what tables have been computed on any of the twenty-five subjects (see § 3) to which it relates, and where they are to be found; and the desire to form a catalogue that shall give a systematic and practical account of the numerical tables in existence that bear upon each of the subjects included has been steadily kept in view; in fact little else has been aimed at. Still, as in the search for and examination of so many books of tables (the Report contains an account of more than 230) a good many works of considerable historical or bibliographical interest came to light, it was not thought desirable to suppress all notice of them. The majority of seventeenth-century works included are described, on account either of their rarity or because they serve to illustrate the history and progress of the subject. Of this kind are NAPIER's 'Canon Mirificus' (1614), containing the first announcement of logarithms, LUDOLF's 'Tetragonometria' (1690), &c.; and when such works have been included, their full titles have been given in § 5, with suitable bibliographical accuracy. It would be a mistake, however, to suppose that all the tables of the seventeenth century have been superseded; VLACQ's 'Arithmetica,' 1628, is the most convenient ten-figure table of logarithms that exists (it has only been reprinted once, and not in so useful a form); and no natural canon published subsequently can bear comparison with PITISCUS, 1613. In performing mathematical calculations, we have had repeated occasion to use both VLACQ and PITISCUS. URSINUS's 'Napierian Canon' (1624) is the largest in existence. The points in which the Report is least complete are the descriptions of common tables of the eighteenth century, and of comparatively modern Italian, Spanish, &c. tables of logarithms. The former class we have purposely omitted, though we have examined many, as they are neither of value intrinsically nor historically; a good many are briefly noticed by De Morgan; and the latter we have not been able to see: several titles will be found in the Babbage Catalogue.

Art. 3. The most valuable detailed list of tables hitherto published is the article TABLES written by De Morgan for Knight's 'English Cyclopædia' (1861). This article first appeared in the 'Penny Cyclopædia' (1842), but it was carefully revised and largely augmented by its author before its reprinting in the 'English Cyclopædia.' In this article are contained notices of 457 tables, many of which, however, are outside the scope of this Report.

We have had occasion to make great use of this article; and whenever De Morgan's name is cited without reference to any work of his, it is always to be understood that it is this article which is referred to. Other works which we have used, but which contain information almost wholly of a bibliographical or historical nature, are:—

(1) 'Historia Matheseos Universæ a mundo condito ad seculum P. C. N. XVI. . . . accedit . . . historia Arithmetices ad nostra tempora,' autore Jo. Christoph. Heilbronner. Lipsiæ, . . . 1742. 1 vol. 4to. The 'Liber quartus sistens Historiam Arithmetices' is at the end of the book, and occupies pp. 723–924.

(2) 'Geschichte der Mathematik,' von Abraham Gotthelf Kästner. Göttingen. (4 vols. 8vo, 1796–1800.) It forms the seventh 'Abtheilung' of the 'Geschichte der Künste und Wissenschaften' (57 vols.). The tables are contained in vol. iii.

(3) 'Bibliotheca Mathematica,' auctore Frid. Guil. Aug. Murhard. Lipsiæ, 1797–1804 (also German title, 'Litteratur der mathematischen Wissenschaften'). 4 vols. 8vo. 'Mathematische Tafeln' is the heading of the fourth division of vol. ii., and occupies pp. 181–201: they are divided into two classes, the first containing logarithmic and trigonometrical tables, and the second the rest; works that Murhard has had in his own hands are marked with an asterisk.

(4) 'Bibliotheca Mathematica sive Criticus Librorum Mathematicorum, ... commode dispositus ab J. Roggio.' Sectio I. 'Libros Arithmeticos et Geometricos complectens.' Tubingæ. . . . . 1830 (also with German title-page). This work we have found very useful. A great number of logarithmic and trigonometrical tables are carefully described in Div. IV. 'Elementar-Geometrie' (B.), pp. 367–410. It is right to add that the titles of tables are to be found in all portions of the work, and are by no means restricted to the arithmetical divisions. We believe that no more than the 'Sectio I.' was ever published.

The following is a continuation of Rogg:—

(5) 'Bibliotheca Mathematica. Catalogue of Books in every branch of Mathematics . . . . which have been published in Germany and other countries from the year 1830 to the middle of 1854.' Edited by L. A. Sohnke, . . . with a complete index of contents. Leipzig and London, 1854. 1 vol. 8vo.

(6) 'Bibliographie Astronomique, avec l'histoire de l'Astronomie. . . . Par Jerôme De La Lande . . . A Paris. . . . An XI.=1803. 1 vol. 4to. A separate index to the general tables is given on pp. 960, 961.

(7) 'Litteratur der Mathematik, Natur- und Gewerbs-Kunde mit Inbegriff der Kriegskunst,' . . . von J. S. Ersch. 'Neue fortgesetzte Ausgabe,' von F. W. Schweigger-Seidel. 'Aus der neuen Ausgabe des Handbuchs der Deutschen Litteratur besonders abgedruckt.' Leipzig, 1828. 1 vol. 8vo.

(8) 'Biographisch-literarisches Handwörterbuch zur Geschichte der exacten Wissenschaften . . . gesammelt' von J. G. Poggendoff. Leipzig, 1863. 2 vols. 8vo.

(9) 'R. P. Claudii Francisci Milliet Dechales Camberiensis e Societate Jesu Cursus seu Mundus Mathematicus.' . . . Lugduni, 1690. 4 vols. fol. The first volume opens with a 'tractatus Proemialis de progressu Matheseos et illustribus Mathematicis;' and pp. 28–37 are devoted to arithmetical bibliography. We may state that a previous edition of 1674, in 3 vols. fol., does not contain the 'De progressu.'

We may also mention De Morgan's 'Arithmetical Books from the invention of printing to the present day,' London, 1847, 8vo, the introduction of which contains useful bibliographical information about the description of books, and Peacock's "History of Arithmetic" in the 'Encyclopædia Metropolitana.' There is one bibliographical work, viz. Scheibel's 'Einleitung zur mathematischen Bücherkenntniss.' Neue Auflage. 3 vols. 8vo, Breslau, 1781 (as given in the Babbage Catalogue), which is continually referred to by Murhard, Rogg, &c., though we have never been able to see a copy in any library to which we have had access, or procure one otherwise. De Morgan says, "Scheibel (additions) may be considered as partly repetition, partly extension, of Heilbronner. He is one of those bibliographers who collect from various sources the names and dates of more editions than those who know catalogues will readily believe in."

It is unnecessary here to mention works on general bibliography, such as Hain, Ebert, Watt, &c., which are well known; we may, however, particularly notice 'Trésor de livres rares et précieux ou Nouveau dictionnaire bibliographique,' par Jean George Théodore Graesse, Dresde [also Geneva, London, and Paris], 1859–1867 (7 vols. including supplement), which might be of use, though we have found the mathematical works it contains very inaccurately described; but this is a fault common to all works of general bibliography.

Montucla, 'Histoire des Mathématiques,' we have not found valuable; but we may call attention to the accurate information given by Delambre in his 'Histoire de l'Astronomie Moderne,' t. i. Paris, 1821; and also in his other histories.

Reuss's 'Repertorium Commentationum a societatibus litterariis editarum,' Gottingæ, 1801–1821, 16 vols. 4to, is a work very similar in its plan to the Royal Society's Catalogue of Scientific Papers, except that it is an *index rerum* instead of an *index auctorum*. The mathematics is contained in vol. vii., the arithmetic occupying pp. 2–31 of that volume. On p. 30 are references to descriptions of calculating and other arithmetical machines.

We have found Nos. XIX. and XX. (on trigonometrical and logarithmic tables) of Hutton's 'Mathematical Tracts,' London, 3 vols. 8vo, 1812, very useful.

Art. 4. The mode of arrangement of this Report (which properly occupies § 3, § 4, and § 5), and the reasons that have led to its adoption, are as follows:—If every table were published separately and formed a work by itself, the obvious course would be to divide them into a certain number of classes according to their contents, to prefix to each class a brief introduction and explanation, and then to give a detailed description, in chronological order, of the tables included under it. This is, in fact, the course that has been pursued with regard to separate tables (*i. e.* works containing either a single table or only tables that come under the same class); § 3 is divided into 25 articles, each article being devoted to one subject:—art. 1, multiplication tables; art. 2, tables of proportional parts, &c. (for the contents of all the articles, see the commencement of § 3). Each article begins with a general account, partly historical, of the subject included in it; and then follow the descriptions of the *separate* tables on that subject. But the majority of works noticed are collections, and include tables that are comprised under several articles; thus Hutton's tables contain Briggian and hyperbolic logarithms of numbers, a natural and logarithmic canon, &c. &c., each of which belongs to a different article. Two courses were therefore open for the treatment of such works:—(1) to describe them under the article

having reference to the first or largest table in the work, and insert cross references under each of the articles concerned with the other tables included in the work; or (2) to describe all collections of tables in a section by themselves, and give references to each of the tables they contain under the appropriate article in § 3. The second course was clearly the more proper, for three reasons—(1) because it was free from the arbitrary element involved in the choice of the leading table, which would be required in the first method, (2) because it was undesirable to overload the articles of § 3 with descriptions of tables not belonging to them, and (3) because reference to the works would be greatly facilitated by placing them in an article by themselves; § 4 therefore contains all works the contents of which do not belong wholly to one of the articles in § 3, or, in other words, which contain at least two tables, the subjects of which are included in different articles of § 3. As the works in § 4 will thus have to be continually referred to separately, they are arranged alphabetically, not chronologically. § 5 is a complete list of all the works containing tables that are described in this Report: and to facilitate its use as an index, a reference is attached to the section, or section and article, in which the work is described.

To take an example of the manner in which the Report is intended to be used. Supposing it were required to know what tables there were of log versed sines; the reader would turn to the beginning of § 3, and, looking down the list of articles, see that, coming under the head of "logarithmic trigonometrical functions," such tables belonged to art. 15. He would accordingly turn to art. 15, and read or glance through the introductory remarks to that article, and the works described there; not finding any book containing log versed sines alone described in the article, he would conclude that no separate table of the kind had come under the notice of the reporter; he would then look at the references to § 4; and if he wished for detailed information with regard to any of those tables, he would examine the descriptions in that section. Any one, on the other hand, desiring to know the contents of any particular work would seek it in § 5; if it occurred there, a reference would be found added either to § 4, or to § 3 and the article in which it is described. No difficulty will be experienced in finding the description if it be remembered that all the works are cited by the author's name and the date; and that while in § 4 they are arranged alphabetically, in the articles of § 3 the arrangement is chronological.

The date is throughout appended to the author's name in citing a work, in order to identify the work in § 5 (the date given being always that assigned to the work in § 5); there is also the further advantage, that any one who requires information only with regard to modern tables, still procurable from the bookseller, need not waste time in seeking the detailed descriptions of works published in the seventeenth and eighteenth centuries.

It may be mentioned that a few works that *do* contain tables of more than one kind, are nevertheless included in § 3: this happens when the smaller tables are insignificant compared with those under which the work is classed; references are then appended also in the articles to which the smaller tables belong.

An asterisk prefixed to an author's name (thus * **Voisin** or * VOISIN) indicates that the description of the work of his referred to has not been derived from inspection. In every case where there is no asterisk, the description has been written by the reporter with the book itself before him.

Art. 5. In all cases where the author of a collection of tables has numbered or marked them himself, his numbering or marking has been followed

in this Report, except in very exceptional circumstances. Where, however, the tables are not numbered or otherwise denoted, they have been marked [T. I.], [T. II.], &c., as it was necessary to have the means of referring to them. Invariably, therefore, where the number of the table is not included in square brackets, it is to be understood that it is the author's own number. Thus T. VII. in any particular work implies that the table in question is numbered VII. in that work, while [T. VII.] implies either that the table has no number, or that the classification in the work is different from that adopted in this Report. Whenever logarithms are mentioned without the epithet hyperbolic or Napierian, common or Briggian logarithms (viz. to base 10) are intended. In some cases, where there might be some doubt, the adjective "common" is introduced. By hyperbolic logarithms are always meant logarithms to the base e (2·71828 . . .); and these are never called *Napierian*, this word being reserved for logarithms of exactly the same kind as those introduced by Napier (see § 3, art. 17). Such a sentence as "Five-figure logarithms to 1000," is always to be understood as meaning "logarithms of numbers from unity to 1000, at intervals of unity to five decimal places:" viz., when the lower limit of a table is not expressed, it is always to be taken as unity; and when the intervals are not mentioned, they are always unity. The term "places" is used throughout for "decimal places" or "decimals," a number "to 3 places" meaning a number given to 3 *places of decimals* (not 3 *figures*). The only exception made to this rule is in the description of tables of common logarithms; the words "seven-figure logarithms, six-figure logarithms," &c., have become by usage so completely recognized as meaning logarithms to seven places, to six places, &c., that it did not seem worth while disturbing the established mode of expression, as it could lead to no error.

The contents of old works have been described in the language and notation of the present day, and not in the manner adopted by their authors; any peculiarities of notation &c. in a table, however, are pointed out. It was long universal, and is still very common, to describe trigonometrical tables as being computed to a certain radius; these are translated into the language of decimals; thus a table "to radius 10,000,000" is described as a table "to seven places," and so on. As a rule the characteristics of the logarithms have been ignored in describing a table; *i. e.* it has not been stated whether the characteristic was given or no, or, if given, what was the understanding on which it was added. In many tables, contained in works intended for a special purpose (as in collections of nautical tables, &c.), arbitrary numbers are added to or subtracted from the characteristics to facilitate their use in working some particular formula; to have included details of this kind would have taken much room, and been really superfluous, as in most cases all that is required to be known in the description of a table of logarithms, is the range of the table, and the number of places to which the mantissæ are given.

We may here mention that an ambiguity occurs in the description of proportional-part tables; thus a "table of proportional parts to tenths" may mean either that the proportional parts are given for one, two, three, &c. tenths of the difference, or else that the numbers that form the proportional-part table are given to one place of decimals. The former is the meaning generally intended; and it would be better if in this case the words "to tenths" were replaced by "for every tenth."

A good many tables had been described before the ambiguity was noticed; but it is believed the context will generally show the true meaning; when the words *to tenths, to hundredths*, &c. are italicized, the latter interpretation (viz. results given to one, two, &c. decimal places) is to be assigned.

Art. 6. To the particular editions of the works described no importance is to be attributed. It would obviously have been impossible to always fix upon the first or last edition as the one to be described; in fact we had no choice; we took what we could get. The list in § 5 always contains portions of the titlepage of the same edition of the work that is described in § 3 or § 4 of the Report; the particular edition chosen was usually determined by the accidental circumstance of its being the first that was examined, any information that was subsequently obtained about other editions being added at the end of the description of the contents of the work in § 3 or § 4. It would have been better to have always taken as the standard the last edition procurable, and pointed out wherein it differed from its predecessors; but this would have required much rewriting of particular portions, and considerably increased the labour of preparation, with a very small increase of regularity in the arrangement of the Report, but with no corresponding increase in its value.

Art. 7. In every case where a table has been described from inspection, all the tables themselves have been examined, and not merely their titlepages, tables of contents, &c. This was of course absolutely necessary in very many instances, as it is comparatively rare that any thing more than a general notion of the contents of a collection of tables can be gathered from the author's explanations; but in any case it was essential if the Report was to have any value for accuracy, because the titles assigned by their authors were sometimes misleading, if not absolutely erroneous; and frequently, even if the more important tables had headings or descriptions prefixed, the smaller ones (which are often more worthy of notice on account of their rarity or mathematical value) were passed over. It must here be remarked that it is never safe to take a description of a table from its author or editor, as it is not a very uncommon thing to give as the contents of a table, not that which can be found from it at once, but what can be obtained from the table by means of additional work, such as an interpolation. Thus, under the heading "Table of logarithms to eight decimals" is sometimes given a table to five places, and a formula from which to calculate the remaining three.

Another case in point is STEINBERGER's table, described in this Report, the titlepage of which describes it as giving the logarithms of all numbers to 1,000,000, when in point of fact it only extends to 10,000—the justification for the title being that two more figures can be interpolated for. It is not to be supposed, when such misstatements occur, that the author of the table has any desire to mislead, as they usually result from ignorance; but it is a matter of regret, when it has become customary (and most properly so) that a table should be described on its title as giving only what can be taken out of it without additional calculation, that this rule should sometimes be violated and a designation given that is, to say the least, misleading. We have also met with such instances as the following:—The title of a book is given in a bookseller's catalogue as (say) "Table of divisors of numbers from 1 to 10,000,000;" but the following words (say), "Part I. from 1 to 150,000" (when perhaps no more was ever published), are left out—an omission of rather an important character as regards the contents and value of the table. Cases of this kind show how imperatively necessary it is to examine the table itself; and whenever the description of a table is taken from an advertisement, bookseller's catalogue, or other second-hand source, there is great liability to error.

Art. 8. The names of authors occurring in the text have been printed in small capitals when the work of theirs alluded to is described in this Report,

otherwise in ordinary roman type: thus we should write "the table was copied from 'BRIGGS's 'Arithmetica' of 1624," because an account of BRIGGS's work is given in the Report; but we should write "the sines were taken from Vieta's 'Canon' 1579," because Vieta's work is not described. This rule is attended to always whenever an author's name is mentioned in juxtaposition with his work, and it will be found to save unnecessary trouble in searching for works not noticed in the Report. Of course all rules are sometimes difficult to carry out; and in cases such as when the author's name and work are separated from one another, or the name occurs frequently in a paragraph by itself, but really in connexion with some work not expressly named each time, &c., we have attempted to carry out the spirit of the rule and no more. An author's name is enclosed in square brackets (thus [**Pell**] or [PELL]) when his name does not occur on the titlepage of the work of his referred to.

Art. 9. The words 8vo, 4to, &c. are used in § 5 to signify works of octavo, quarto, &c. size, without reference to the number of pages to the sheet. They are merely intended to give a rough idea of the size and shape of the work, which is better done by using them in a general sense than by attaching to them their technical meanings. The words "large" or "small" have been prefixed when the size was markedly different from what is usual. It must be remembered that two hundred years ago all the sizes were much smaller than at present, so that the usual quarto page of 1650 is smaller than an octavo page of our day, though the shape is of course more square. Old works are generally described as they would have been at the time; but it sometimes may have happened that a true quarto of old date is here given as octavo, &c.: this caution is necessary for those who might use § 5 bibliographically. Whenever, in transcribing portions of works in § 5, words have been omitted from the titlepage, dots have been inserted to mark the omissions. We may mention that we have used the word *reprint* in its proper sense; viz. we have not spoken of a reprint except when the type was reset.

Art. 10. In the preparation of this Report extensive use has been made of the libraries of the British Museum, the Royal Society, the University of Cambridge, the Royal Observatory, Trinity College (Cambridge), and the Royal Astronomical Society, in one or other of which the majority of the works noticed are contained. We have also, through the kindness of Professor Henrici, been enabled to consult the Graves Library at University College, London, which contains an almost unrivalled collection of old mathematical works; but as they are not yet arranged, it is not possible to find any particular work without great expenditure of time and labour. The De-Morgan library at the London University is also still in process of arrangement, and is therefore inaccessible for the present. By the kindness of Mr. Tucker, who forwarded us an early copy of the sale-catalogue of the late Mr. Babbage's library, we have been enabled to extract several titles from it, and identify works of the titles of which we had only imperfect descriptions; but we have not been able to see any of the books themselves. It must not be understood that the Report contains notices of all the books of mathematical tables contained in the libraries mentioned at the beginning of this article. For instance, the Royal Society's catalogue contains the titles of several works that should be included but which we have not yet examined; and of course no one can know what tables there are in such libraries as those of the British Museum or the Cambridge University, where there is no catalogue of subjects. For the omissions we could have rectified we must plead in excuse the already great extent of the Report, and consequent necessity of drawing the line somewhere. Of course many of the works noticed are either in our own

possession or were lent by friends; and we must acknowledge the kind assistance rendered by Mr. C. W. Merrifield, F.R.S., of whose mathematical library we hope to make more use in a future Report.

Art. 11. The Report is avowedly very imperfect; it contains probably not one half of the works that have as good a right to be noticed as those that are included. This defect will be remedied by the publication of an Appendix or additional Report on the same subject, probably after the appearance of the Reports on the other divisions. As it would be clearly impossible to have made this Report perfect (and had it been possible, it would have occupied more space than could be given to it), an Appendix giving the results of the examinations of the memoirs, transactions, &c. in reference to this class of tables would have had in any case to be added after the completion of the other divisions; and on this account it seemed unnecessary to take especial pains to procure works that were clearly of no very great importance, or to insert imperfect second-hand accounts of tables that would in all probability be met with in the course of the formation of the subsequent Reports. Invariably, however, whenever a reference was found to a table that seemed of importance, no pains have been spared in the endeavour to obtain and examine a copy; in the event of these efforts being fruitless, a notice of the work compiled from other accounts has been given, with an intimation of the source whence the information was derived; but only three or four works are included that have not come under the eye of the reporter. It is probable that there may have been published recent works on the continent no copy of which is contained in any of the public libraries of this country; and on this account it will probably be found very difficult to make the list perfect. The present Report is, however, so far complete that the Committee think they may ask mathematicians or computers who are acquainted with any works not included in it or in De Morgan, to inform them of the fact. It is only in this way that completeness can be obtained, as although, by an examination of the transactions &c. to which references are given at the beginning of the Royal Society's catalogue, the completion of the accounts of tables contained in memoirs &c. would be merely a matter of time and labour on the part of the members of the Committee, the discovery and description of books printed in out-of-the-way places, or for private circulation, can only be effected by the cooperation of mathematicians who may happen to possess copies*. The Report, however, as it now stands, will be found to contain more information about tables than is to be found anywhere else; in fact, except De Morgan's list (referred to in art. 3 of this section), we know no place where any attempt is made to cover the ground included in this Report; and though De Morgan has referred to more works than are described here in detail (even when commercial tables are excluded), it must be borne in mind that his descriptions are too short and general to be of great value, that more than a third of his accounts are compiled from sources other than the original works, and that he has made no attempt to do more than roughly classify the *works* (not the tables); in fact a more detailed description or classification was excluded by the plan of his article, which notwithstanding gives a great deal of information in a very small space.

Art. 12. By an oversight (which was not discovered till it was too late to remedy it) we have excluded from the Report *traverse tables*, viz. Difference-of-latitude and Departure tables, which under the head of multiples of sines and cosines ought to have been noticed. Such tables are of general use in

* It is requested that communications may be addressed to Mr. J. W. L. Glaisher, Trinity College, Cambridge.

all mathematics, as they are in reality merely tables for the solution of right-angled triangles; we have noticed one such table (Massaloup, § 3, art. 10), which was constructed for mining- (not nautical) purposes.

We hope to repair the omission by appending a separate list of traverse tables to a future Report.

Art. 13. A very important incidental gain that it was hoped would be afforded by the present Report, was the opportunity of correcting errors in logarithmic and other tables by giving references to the places in which errata-lists had been published. In the introductions or prefaces to works containing tables, it is usual to give a list of the errors that have been found during their preparation in previous tables; and as few possessors of a work can be acquainted with the publications that have appeared subsequently, it was thought that by referring, under each title, to the works or periodicals in which lists of errata in it had appeared, an important service would be rendered. It was soon evident, however, that it was impossible to deal adequately with the subject of errors in this manner. Many of the important collections have been through very numerous editions; and it was not always stated in which editions the errors were found; and when the edition was stated, it was doubtful (without examination) whether the errata-list in question had come under the eye of the editor, and the errors been corrected in subsequent editions, or not. In the case of stereotyped tables, successive *tirages* are more and more accurate; and in regard to collections of such tables published long ago, as, for example, Callet (first published in 1783, though since reset), it seems useless to waste space by giving references to the numerous errata-lists that have been published, some of which must necessarily relate only to the earlier *tirages*, and must have been corrected long ago. This is the case with all the chief tables, and only in particular instances, when circumstances rendered it probable that the errata-lists would be of use, have references been given to them. As, however, this state of affairs is very unsatisfactory, it is hoped that in a subsequent Report a complete list of errors in later editions of the most-used mathematical tables, still unsuperseded, may be given; but it is necessary first to be satisfied that the errata given are not erroneous themselves. Many of the chief modern lists of errata are noticed in this Report, and also others that it seemed desirable to give references to at once; but we have made no effort to deal with the matter in a complete manner. It is much to to be regretted that it is not usual for editors of a new edition of a table to give a list of the errors that occurred in former editions, and have been corrected in that edition. It is only fair for the purchaser of a new edition of a work to be informed wherein it differs from its predecessors; but unfortunately the object of the editor and publisher is to sell as many copies of the new edition, not to render the old as valuable as the new. It is proper to add, however, that usually, when tables are published by a mathematician for the advancement of science, and not by a bookseller and editor for the sake of profit, an exception is made to this rule, and errata are freely acknowledged. A remark made by De Morgan with reference to mathematical books in general, viz. that the absence of a list of errata means, not that there are no errors, but merely that they have not been found out, is more applicable to tables than to any other class of work, in spite of the care usually bestowed on them; and an error in a table is far more fatal than an error in any other class of work, as there is no context (as far as the user is concerned) to show immediately that the result taken from the table is erroneous. The subject of errors will particularly occupy the attention of the Committee in a future Report.

Art. 14. The whole of the work required in the preparation of the Report has been carefully performed; and we believe that not many inaccuracies will be found. Every work noticed, except only three or four, has been described from actual inspection; and the account has invariably been written with the book before us. Every one, however, who has had any experience of bibliographical work knows how impossible it is to be always accurate; the work has often to be performed in public libraries open only for a few hours in the day, so that any one who has not an unlimited number of days at his command, must sometimes work under pressure. Omissions are thus made, which, when discovered during the revision six months afterwards, cannot be rectified without great loss of time, even if it be remembered what library it was that contained the work in question. The references from one part of the Report to another will also, it is believed, be found correct; but as the whole plan and arrangement have been altered in the course of the year over which the preparation of the Report has lasted, it is possible that some of the old references may remain still uncorrected. If this should be found to be the case, not much difficulty can ever be experienced in seeing what is meant with the aid of the list of articles at the beginning of § 3, and the list of works in § 5; also if any misprints (such as T. II. for T. III. &c.) should escape notice in the correction of the proofs, the reader will be enabled to correct these without much waste of time. Lists of errata and corrections, should such be needed, will be given in subsequent Reports. Whenever we have made a statement on some other authority than that of our own observation, we have invariably stated it, though we are aware that we thus lay ourselves open to the imputation of not having verified facts of the accuracy of which we might have assured ourselves; but, as De Morgan has observed, the possibility of writing a history entirely from personal observation of the originals has not yet been demonstrated.

§ 3. *Separate Tables, arranged according to the nature of their contents; with Introductory Remarks on each of the several kinds of Tables included in the present Report.*

This section is divided into twenty-five articles, the subject matter of which is as follows:—

Art. 1. Multiplication tables.
2. Tables of proportional parts.
3. Tables of quarter squares.
4. Tables of squares, cubes, square roots, and cube roots.
5. Tables of powers higher than cubes.
6. Tables for the expression of vulgar fractions as decimals.
7. Tables of reciprocals.
8. Tables of divisors (factor tables), and tables of primes.
9. Sexagesimal and sexcentenary tables.
10. Tables of natural trigonometrical functions.
11. Lengths (or longitudes) of circular arcs.
12. Tables for the expression of hours, minutes, &c. as decimals of a day, and for the conversion of time into space, and *vice versâ*.
13. Tables of (Briggian) logarithms of numbers.
14. Tables of antilogarithms.
15. Tables of (Briggian) logarithmic trigonometrical functions.
16. Tables of hyperbolic logarithms (viz. logarithms to base 2·71828 . . .).
17. Napierian logarithms (not to base 2·71828 . . .).

Art. 18. Logistic and proportional logarithms.
19. Tables of Gaussian logarithms.
20. Tables to convert Briggian into hyperbolic logarithms, and *vice versâ*,
21. Interpolation tables.
22. Mensuration tables.
23. Dual logarithms.
24. Mathematical constants.
25. Miscellaneous tables, figurate numbers, &c.

Art. 1. *Multiplication Tables.*

The use of the multiplication table is so essential a part of the history of Numeration and Arithmetic, that for information with regard to its introduction and application we must refer to Peacock's 'History of Arithmetic' in the 'Encyclopædia Metropolitana,' to De Morgan's 'Arithmetical Books' (London, 1847), as well as to Heilbronner, Delambre, &c. (see § 2, art. 3), to Leslie's 'Philosophy of Arithmetic,' and perhaps to Barlow's 'Theory of Numbers' (London, 1811), in most of which references to other works will be found. There is abundant evidence that, till comparatively recent times (say the beginning of the eighteenth century), multiplication was regarded as a most laborious operation; this is testified not only indirectly by the very simple examples given in old arithmetics, but explicitly by Decker in his 'Eerste Deel vande Nieuwe Telkonst' (see Phil. Mag. Suppl. Number, Dec. 1872). The great popularity of Napier's bones, and the eagerness with which they were received all over Europe, show how great an assistance the simplest contrivance for reducing the labour of multiplications was considered to be. It would be interesting to know how much of the multiplication computers were in the habit of committing to memory, as the bones would be no great help to any one who knew it as far as nine times nine. In this Report, however, we are only concerned with extended multiplication tables (viz. such as are to be used as tables, and were not intended to be committed to memory). The earliest printed table of multiplication we have seen referred to is Thomas Finck's 'Tabulæ Multiplicationis et Divisionis, seorsim etiam Monetæ Danicæ accommodatæ,' Hafniæ, 1604 (which title De Morgan obtained from Prof. Werlauff, Royal Librarian at Copenhagen); but the work, from its title, must have been rather a ready reckoner than a proper scientific table. The earliest large table, which, strange to say, is still as extensive as any (it has been equalled, but not surpassed by CRELLE, 1864), is HERWART AB HOHENBURG's 'Tabulæ Arithmeticæ προσθαφαιρεσεως Universales,' 1610, described at length below. Of double-entry tables, CRELLE's 'Rechentafeln,' 1864, is the most useful, and the most used, for general purposes. The other important tables are chiefly for multiplication by a single digit.

A multiplication table is usually of double entry, the two arguments being the two factors; and when so arranged, it is frequently called a "Pythagorean Table." The great amount of room occupied by Pythagorean tables (no table so arranged could extend to $1000 \times 10,000$, and be of practicable size) has directed attention to modes of arrangement by which multiplication can be performed by a table of single entry; the most important of these are tables of quarter-squares, which are described in § 3, art. 3, where are also added some remarks on multiplication tables of single entry. See also DILLING, described below.

It is almost unnecessary to add that, when not more than seven or ten figures are required, multiplication can be performed at once by logarithms, which (though not the best method for two factors when either a Pythagorean

or quarter-square table of suitable extent is at hand) have the advantage that by their means any number of factors can be multiplied together at once.

GRUSON's table, 1798, is for multiplications of a somewhat different kind from the rest.

CRELLE, in the introduction to his 'Rechentafeln' (1820), mentions a work, 'Tables de Multiplication, à l'usage de MM. les géomètres, de Mm. les ingenieurs verificateurs du Cadastre, etc.' sec. edit. Paris, Chez Valace, 1812, which he says extends to 500×500, and occupies 500 quarto pages; while, he adds, his own work, which is four times the extent, occupies only 1800 octavo pages. For the full titles of Picarte's 'Tables de Multiplication' and 'Tableau Pithagorique,' see under PICARTE (1861), in § 3, art. 7.

Closely connected with multiplication tables are so-called *Proportional-parts* tables (described in the next article); and very frequently in the latter the last figure is not contracted, so that by a mere change of the position of the decimal point they become tables of multiples.

Herwart ab Hohenburg, 1610. Multiplication table, from 2×1 to 1000×1000. The thousand multiples of any one of the numbers are contained on the same page, so that (as the number 1 is omitted) there are 999 pages of tables. By a strange oversight, the numbering begins with 1 on the first page of the table instead of 2, so that the multiples of n are found on page $n-1$: this is inconvenient, as the number of the page alone appears on it, so that (say) to find a multiple of 898 we seek the page headed 897. Each page contains 100 lines, numbered in the left-hand column 1, 2, 3, . . . ; and besides this column of arguments there are ten columns headed 0, 100, . . . 900. The first figure of the multiplier is therefore found at the top of the column, and the last two in the left-hand column (on p. 3 it will be noticed 200 and 300 are interchanged at the top of the columns). There being more than 1000 pages of thick paper, the book, as De Morgan has observed, forms a folio of almost unique thickness. Also, as the pages contain 100 lines, pretty well leaded, the size of the book is very large; so that Leslie (Philosophy of Arithmetic, 2nd edit. 1820, p. 246) was quite right in calling it "a very ponderous folio." De Morgan says "the book is excessively rare; a copy sold by auction a few years ago was the only one we ever saw."

Kästner ('Geschichte,' t. iii. p. 8) quotes the remark of Heilbronner (who gives the title of the work, 'Hist. Math.' p. 801), "Docet in his tabulis sine abaco multiplicationem atque divisionem perficere," &c., and adds that Heilbronner could not have seen the work, or he would have described it; he remembers to have read that it was like a great multiplication table. The title is given by Murhard, and marked with an asterisk to show that he had seen a copy. Rogg gives the title very imperfectly; and it is clear the work has not been in his hands. There is a complete copy in the British Museum, and a copy in the Graves Library; but the latter is imperfect, the pages 12–25, 120–145, and 468–517 having been lost, and their places supplied with blank paper. On account of the rarity of the work, and the great interest attaching to it from the time when it was published, we have thought it worth while to give the title in full in § 5. The clearness of the type and the extent of the table (which has not been surpassed, and only equalled by CRELLE, 1864), taken in connexion with its early date (four years before NAPIER's 'Canon Mirificus'), give the work a peculiar interest. De Morgan writes:—"it is truly remarkable that while the difficulties of trigonometrical

calculations were stimulating the invention of logarithms, they were also giving rise to this the earliest work of extended tabulated multiplication. Herwart passes for the author; but nothing indicates more than that the manuscript was found in his possession." We have seen the statement that while Napier solved triangles by logarithms, Herwart did so by prosthaphæresis, and others of the like kind, the inference being that Herwart invented a method which has been superseded by logarithms; this (if the present work is the source of the statement) is incorrect, Herwart's table being merely useful in facilitating the multiplications required in the formulæ.

There are in the British Museum three other works of Herwart ab Hohenburg: viz., 'Thesaurus Hieroglyphicorum e museo Joannis Georgii Herwart ab Hohenburg...' (Obl. fol. Munich?, 1610?); 'Novæ, veræ et exactè ad calculum... Chronologiæ è museo...' Small 4to, 1612; and 'Ludovicus Quartus Imperator defensus... ab Joanne Georgio Herwarto' &c. 4to. Munich, 1618 (the middle one of which is given in Lalande's Bib. Ast.). We have looked at these three books in the hope that some mention might be made in them of the table, or some information given about Herwart's Museum; but they appear to contain nothing of the kind. We have seen also the titles of several other works of Herwart's, and references to where particulars of his life are to be found; so that, considering the attention so large a work as his table must have received from contemporary mathematicians, we still have hopes of being able to bring to light some information with regard to its calculator, his objects, &c.

It should be stated that Herwart ab Hohenburg is spoken of quite as frequently by the name of Hohenburg as by that of Herwart.

The author of the anonymous table (1793) described below, states that many errors were found in HERWART, and that Schübler (whose table we have not seen) was much more correct.

Riley, 1775. The first nine multiples of all numbers from 1 to 5280. The multiples of the same number are placed one under the other, the factors 1, 2 . . . 9 being three times repeated on the page, which contains ten columns of results and twenty-seven lines.

The preface is signed Geo. Riley and T. O'B. Macmahon. There is an advertisement of Riley's "historical playing-cards" &c. at the end, and of several works by Macmahon. On the relation of this book to another, "printed for J. Plummer" (anonymous) in the same year, see De Morgan.

Anonymous, 1793. Multiplication table exhibiting products from 2×13 to 100×1000, arranged so that there are 100 multiples (in two columns) of four numbers on each page, which therefore contains eight columns.

Gruson, 1798. The first part of this book contains a number of tables, the description of any one of which will explain the arrangement. Take the table 36: it has ten columns, headed 0, 1, 2, . . . , 9 (as have all the other tables), and 36 lines, numbered 0, 1, 2, . . . , 35; we find in column 6 and line 21 (say) $237=6\times 36+21$. The use of the table is as follows:—suppose it required to find the number of inches in 6 yards 21 inches; 36 in. $=1$ yd., we find table 36, column 6, line 21, and have the result given in inches. There are tables for all numbers from 1 to 100, and for primes from 100 to 400, the number of lines in each table being equal to the number of the table. The use of the tables in performing ordinary divisions and multiplications when there are four or more figures in the divisor or dividend, &c. is fully explained by the author in the introduction. When used for division, the table gives the quotient and the remainder.

There is also given a table of all simple divisions of numbers (not divisible

by 2, 3, or 5) to 10,500. A short and grandiloquent dedication to the French Institute is prefixed.

Rogg gives also a German title, 'Pinacothek, oder Sammlung allgemeinnützlicher Tafeln für Jedermann' &c.

Gruson, 1799. A table of products to $9\times10{,}000$. The pages, which are very large (containing 125 lines), are divided into two by a vertical line, each half page containing ten columns, giving the numbers and their first nine multiples: the first half of the first page thus ends at 9×124, the second half at 9×249; and there are 1992 tabular results to the page. The table has only one tenth of the range of BRETSCHNEIDER's; but the result is given at once; however, the large size of the page (almost, if not quite, the largest we have seen for a table) is a great disadvantage. There are two pages of explanation &c.

The title describes the table as extending to 100,000, the above being only the first part. We do not know whether any more was published, but think probably not. Rogg mentions no more. At the end of the introduction three errors occurring *in some copies* are given.

Martin, 1801. This is a large collection of tables on money-changing, rentes, weights and measures, &c. The only part of the book that needs notice here is Chapter XI., which contains a multiplication table giving the first nine multiples of the numbers from 101 to 1052 (19 pp.).

Dilling, 1826. In the use of a table of logarithms to multiply numbers together, the logarithms used are of no value in themselves, being got rid of before the final result. If, therefore, letters $a, b, c, \ldots$ be used instead, we have no occasion to know the values of any one of them, but only the way in which they are related to one another. The present table is constructed for numbers up to 1000 on this principle; within this range there are about 170 primes, the logarithms of which have to be denoted by separate symbols, $a, b, \ldots, z, a_1, b_1, \ldots,$ &c.; the powers of 2 are denoted by numbers; thus $\log(2^2)=2$, $\log(2^3)=3$, &c.; and the logarithms of any number to 1000 can be easily expressed in not more than four terms; thus $\log 84=2+a+c$. There is also a table of antilogarithms arranged according to the last letter involved; thus $\log 21=a+c$, $\log 15=a+b$, the sum $=2a+b+c$; and entering the antilogarithmic table at c, we find 315 the product. We can thus only multiply numbers whose product is less than 1000; and a table of products of the same size would certainly have been more useful. The table can of course be used for division, square roots, &c., but only if the result is integral, so that it is little more than a matter of curiosity. This table was intended, however, only as a specimen, to be followed by a larger one to 10,000. We believe the continuation was not published; and Rogg refers to no other work of Dilling.

The work, although nominally a table of logarithms, is included in this article, as it is really a multiplication table. It is the only table we have met with involving a principle which at one time would have been of value with respect to multiplication, viz. to resolve the numbers into their prime factors, and multiply them by adding their factors. Thus $21=3\times7$, $15=3\times5$, and their product $315=3^2\times5\times7$; if therefore we had a table giving the prime factors of all numbers from 1 to 1000, arranged in order, and another table of like extent giving the numbers corresponding to the same products of factors, arranged with the largest factor first, and the others in descending order, so as to facilitate the entry, we could perform multiplication (where the product does not exceed 1000) by addition only. In the construction of such a table it would soon be found convenient to replace the two and three

figure primes by letters, to save room, and, in fact, to use letters throughout—and further to simplify the printing by writing a^4 as $4a$, &c., which would do equally well; we then have DILLING's tables, which have not the smallest connexion with logarithms. Such a table might once have been found useful; but the slightest consideration shows that (except as a factor table) it would be all but valueless now. The space a large table of the kind would occupy, the impossibility of arranging the antifactor table so as to admit of easy entry, and the great convenience of existing tables (both Pythagorean and logarithmic) are alone sufficient to prove this.

Crelle, 1836. This table occupies 1000 pages, and gives the product of a number of seven figures by 1, 2, . . . , 9, by a double operation, very much in the same manner as BRETSCHNEIDER's does for a number of five: viz., each page is divided into two tables; thus, to multiply 9382477 by 7, we turn to page 825, and enter the right-hand table at line 77, column 7, where we find 77339; we then enter the left-hand table on the same page, at line 93, column 7, and find 656, so that the product required is 65677339. We think for numbers seven figures long the table effects a considerable saving of time, as it is as easy to use as BRETSCHNEIDER's for five figures. It would take some little practice to use the table rapidly in all cases, as of course the mode of entry, &c. must be varied according as the number consists of seven, six, five, &c. figures; but the value of a table is measured not by the trouble required to learn to use it, but by the time saved by means of it *after* the computer has learnt its use.

Bretschneider, 1841. This table is for the multiplication of any number up to 100,000 by a single digit. On each page there are two tables, the upper of which occupies ten lines, and the lower fifty. An example will show the method of using the table. Suppose it required to multiply 56878 by 7, then the table is entered on the page headed 6800 (the headings run from 0 to 99, with two ciphers added to each). Facing 78 in the lower table we find *146; and in the upper table facing 568, in the column for 7, we find 397; the product required is therefore 398146, the third figure being increased because the 146 was marked by an asterisk. The arguments in the upper table, on the page headed 6800, are 68, 168, 268 . . . 968 (twice repeated for the two cases when succeeding numbers are less and greater than 50), and also 1, 2 . . . 9, as the table is of double entry.

The arrangement of the table is thus very ingenious; but, as De Morgan has remarked, multiplication by a single digit is so simple an operation that it is questionable how far a table is serviceable when its use requires three distinct points to be attended to.

The introduction (10 pages) gives a complete explanation of how the table can be used when the number of figures is greater than five. Having made some use of the table for this purpose, we do not think any time is saved by it; at all events, not until the computer has had much practice in using it.

Crelle, 1864. This magnificent table gives products up to 1000×1000, arranged in a most convenient and elegant manner, one consequence of which is that all the multiples of any number appear on the same page. It is also very easy to get used to the arrangement of the table, which is as useful for divisions as multiplications. It can be used for multiplying numbers which contain more than three figures, by performing the operation, three figures at a time; but it requires some practice to do this readily; and a similar remark applies to the extraction of square roots.

There is one great inconvenience that every computer must feel in using the work, viz. that the multiples of numbers ending in 0 are omitted, so that,

for example, we pass from 39 to 41. It is quite true that the columns for 40 are the same as those for 4 with the addition of a 0; but the awkwardness of turning to opposite ends of the book for (say) 889 and 890, and then having to add a 0 to the latter, is very great. It is a pity that a desire to save a few pages should have been allowed to impair the utility (and it does so most seriously) of so fine a table. The matter is referred to in the preface, where it is said that Crelle, "after mature reflection," decided to omit these numbers.

The original edition was published in 1820, and consisted of two thick octavo volumes, the first proceeding as far as 500×1000, and the second completing the table to 1000×1000. The inconvenience referred to above is felt more strongly in this than in the one-volume edition, as frequently the numbers ending in 0 have to be sought in a different volume from the others. Both editions are, we believe, very accurate. There are 3 pp. of errata (pp. xvii–xix) at the beginning of the edition of 1820. De Morgan gives 1857 as the date of Bremiker's reprint, and says he has heard that other copies bear the date 1859, and have no editor's name.

Laundy, 1865. The first nine multiples of all numbers from 1 to 100,000, given by a double arrangement: viz., if it is required to multiply 15395 by 8, we enter the table on p. 4 (as 395 is intermediate to 300 and 400) at 15, and in column 8 find 122; we enter another table on the same page at 395, and in column 8 find 160; the product is therefore 123160. We take this number instead of 122160 because in the column headed 8, first used, there appears the note [375]*, the meaning of which is that if the last three figures of the number exceed 375 (they are 395 in the above example) the third figure is to be increased by unity. The table is thus seen to be the same *in principle* as Bretschneider, but not quite so convenient. There are the same objections to this as to the latter table. The present table occupies 10 pp. 4to, and Bretschneider's 99 pp. 8vo.

Mr. Laundy remarks in his preface that Crelle's 'Erleichterungs-Tafel,' 1836, although one hundred times as large as his, "must not be estimated as presenting advantages proportionate to its vast difference of extent." In this we scarcely agree; for it is only when the numbers are six or seven figures long that one begins to feel the advantages of a table for so simple an operation as multiplication by a single digit, and Crelle's table would not take much longer to use than the present.

The following is a list of references to § 4:—

Multiplication Tables.—Dodson, 1747, T. XXXVIII. to 9×9999; Hutton, 1781 [T. I.] to 100×1000; Callet, 1853 [T. VIII.]; Schrön, 1860, T. III.; Parkhurst, 1871, T. XXVI., XXXIII., and XXXIV.; see also Leslie, 1820, § 3, art. 3, and Wucherer, 1796, T. II. (§ 3, art. 6.)

Art. 2. *Tables of Proportional Parts.*

By a table of the proportional parts of any number x is usually understood, a table giving $\frac{1}{10}x$, $\frac{2}{10}x$, ... $\frac{9}{10}x$ true to the nearest unit. Of course the assumption of 10 as a divisor is conventional, and any table giving $\frac{x}{a}$, $\frac{2x}{a}$, ... $\frac{(a-1)x}{a}$ would equally be called a proportional-part table. Ordinary proportional-part tables (viz. in which $a=10$) are given at the sides of the pages in all good seven-figure tables of logarithms that extend from 10,000 to 100,000. The difference between consecutive logarithms at the commencement of the tables (viz. at 10,000) is 434, and at the end is therefore 43; so that a seven-figure table of the above extent gives the proportional

parts of all numbers from 43 to 434 (note that near the commencement of the table, viz. from diff. 434 to diff. 346, the proportional parts are only given for every other difference in some tables; whether a table gives the proportional parts of all the differences or not is generally noted in § 4). Several seven-figure tables extend to 108,000; and for the last 8000 the differences decrease from 434 to 403. Tables in which $a=60$ often accompany canons of trigonometrical functions that give the results for every minute, for convenience of interpolating for seconds; such must be sought from the descriptions of trigonometrical tables in § 3, arts. 10 and 15, and in § 4; we have also seen tables for which $a=30$, where the functions are tabulated for every two minutes or two seconds.

There are several tables to which proportional parts of the differences to hundredths (viz. in which $a=100$) are attached, *e.g.* Gray (§ 3, art. 19), Filipowski (§ 4), and Pineto (§ 3, art. 13); but the ranges of the differences are generally so small that it is not worth while giving references. In Pineto, for instance, the range of the differences is only from 4295 to 4343 (in this work multiples are given, the last two figures being separated by a comma).

The only separate table of proportional parts, properly so called, that we have seen, is

Bremiker, 1843 ('Tafel der Proportionaltheile'). Proportional parts *to hundredths* (viz. multiples from 1 to 100, with the last figure omitted, and the last but one corrected) of all numbers from 70 to 699. A very useful table, chiefly intended for use in interpolating for the sixth and seventh figures in logarithmic calculations.

T. III. of Schrön (§ 4) (which is there called an Interpolation Table) is a large table of proportional parts.

It is to be noticed that all multiplication tables are, or rather can be used as proportional-part tables. A table of multiples, with the last figure omitted, and the last but one corrected (which can be done at sight), is a proportional-part table to tenths; and if the last two figures are omitted, and the last remaining figure corrected, to hundredths (see therefore § 3, arts. 1 and 3).

It is proper here to allude to slide-rules and other mechanical appliances for working proportions &c. A card intended to do the work of a very large slide-rule is described in § 4 (Everett); and some information and references about slide-rules of different shapes will be found in a paper "On a New Proportion Table," by Prof. Everett, in the Phil. Mag. for Nov. 1866.

The following are references to works described in § 4:—

Tables of Proportional Parts.—Sir J. Moore, 1681 [T. II.]; Ducom, 1820, T. XX.; Lynn, 1827, T. Z; Callet, 1853 [T. VIII.]; Schrön, 1860, T. III.

Art. 3. *Tables of Quarter Squares.*

Tables of quarter squares have for their object to facilitate the performance of multiplications; and the principle on which their utility depends is contained in the formula

$$ab=\tfrac{1}{4}(a+b)^2-\tfrac{1}{4}(a-b)^2,$$

so that with such a table to multiply two numbers we subtract the quarter square of the difference from that of their sum; the multiplication is therefore replaced by an addition, a subtraction, two single entries of the tables, and a final subtraction—a very considerable saving if the numbers be high. The work is more than with a product table, where a double entry gives the result at once; but the quarter squares occupy much less space, and can

therefore be tabulated to a much greater extent without inconvenience. In tables of quarter squares the fraction $\frac{1}{4}$ which occurs when the number is odd is invariably left out; this gives rise to no difficulty, as the sum and difference of two numbers must be *both* odd or *both* even.

A product can, of course, be obtained by logarithms with about the same facility as by a table of quarter squares; but the latter is preferable when all the figures of the result are required.

LUDOLF, 1690 (see § 3, art. 4), in the preface to his 'Tetragonometria,' explains the method of quarter squares completely, and shows how his table is to be used for the purposes of multiplication. The earliest table of *quarter* squares De Morgan had heard of was VOISIN, 1817; but CENTNERSCHWER (see below) refers to one by Bürger of the same date, the full title of which we have quoted from Rogg.

CRELLE, in the preface to the first edition of his 'Rechentafeln' (1820, p. xv.), speaks of "Quadrat-Tafeln nach Laplace und Gergonne, mittelst welcher sich Producte finden lassen," &c. The allusion to Laplace doubtless refers to the memoir in the 'Journal Polytechnique,' noticed further on in this article; but we cannot give the reference to Gergonne.

The largest table of quarter squares that has been constructed is that published by the late Mr. LAUNDY, which extends as far as the quarter square of 100,000; it would be desirable, however, to have a table of double this extent (viz. to 200,000), which would perform at once multiplications of five figures by five figures (Mr. Laundy's table is only directly available when the sum of the numbers to be multiplied is also of five figures). The late General Shortrede constructed such a table, we believe, in India, but unfortunately abandoned the idea of publishing it on his return to England, where he found so much of the field already covered by Laundy's tables. De Morgan, writing when it was anticipated that Shortrede's table would be published, suggested that it would be convenient that the second half should appear first; and we should much like to see the publication of a quarter-square table of the numbers from 100,000 to 200,000.

Mr. LAUNDY, in the preface to his 'Table of Quarter Squares' (p. vi), says that Galbraith, in his 'General Tables,' 2nd edit. 1836, which were intended as a supplement to the second edition of his 'Mathematical and Astronomical Tables,' gives a table (T. xxxiv.) of quarter squares of numbers from 1 to 3149. This book is neither in the British Museum nor the Cambridge University Library. The second edition of his 'Mathematical and Astronomical Tables' (1834) contains no such table. There is, however, no doubt about the existence of the work, as the Babbage Catalogue contains the title "Galbraith, W., New and concise General Tables for computing the Obliquity of the Ecliptic, &c. Edinburgh, 1836."

In 1854, Prof. Sylvester having seen a paper in Gergonne in which the method was referred to, and not being aware that tables of quarter squares for facilitating multiplications had been published, suggested the calculation of such tables, in two papers—"Note on a Formula by aid of which, and of a table of single entry, the continued product of any set of numbers . . . may be effected by additions and subtractions only without the use of Logarithms" (Philosophical Magazine, S. 4. vol. vii. p. 430), and "On Multiplication by aid of a Table of Single Entry" (Assurance Magazine, vol. iv. p. 236). Both these papers were probably written together; but there is added to the former a postscript, in which reference is made to VOISIN and Shortrede's manuscript. Prof. Sylvester gives a generalization of the formula for ab as the difference of two squares, in which the product $a_1 a_2 \ldots a_n$ is expressed as the sum of

nth powers of $a_1, a_2, \ldots a_n$, connected by additive or subtractive signs. For the product of three quantities the formula is

$$abc=\tfrac{1}{24}\{(a+b+c)^3-(a+b-c)^3-(c+a-b)^3-(b+c-a)^3\}.$$

And at the end of the 'Philosophical-Magazine' paper, Prof. Sylvester has added some remarks on how a table to give triple products should be arranged.

At the end of a memoir, "Sur divers points d'Analyse," Laplace has given a section "Sur la Réduction des Fonctions en Tables" (Journal de l'Ecole Polytechnique, Cah. xv. t. viii. pp. 258–265, 1809), in which he has briefly discussed the question of multiplication by a table of single entry. His analysis leads him to the method of logarithms, quarter squares, and also to the formula $\sin a \sin b=\frac{1}{2}\{\cos(a-b)-\cos(a+b)\}$, by which multiplication can be performed by means of a table of sines and cosines. On this he remarks, "Cette manière ingénieuse de faire servir des tables de sinus à la multiplication des nombres, fut imaginée et employée un siècle environ avant l'invention des logarithmes."

It is worth notice that the quarter-square formula is deduced at once from $\sin a \sin b=\frac{1}{2}\{\cos(a-b)-\cos(a+b)\}$, by expanding the trigonometrical functions and equating the terms of two dimensions; similarly from $\sin a \sin b \sin c=\frac{1}{4}\{\sin(a+c-b)+\sin(a+b-c)+\sin(b+c-a)-\sin(a+b+c)\}$, by equating the terms of three dimensions, we obtain $abc=\frac{1}{24}\{(a+b+c)^3-\&c.\}$, as written down above, and so on, the general law being easily seen. We may remark that there is an important distinction between the trigonometrical formulæ and the algebraical deductions from them, viz. that by the latter to multiply two factors we require a table of squares, to multiply three a table of cubes, and so on; *i. e.* each different number of factors requires a separate table; while one and the same table of sines and cosines will serve to multiply any number of factors. This latter property is shared by tables of logarithms of numbers, the use of which is of course in every way preferable; still it is interesting to note the inferiority that theoretically attaches to the algebraical compared with the trigonometrical formulæ. Other remarks on the subject of multiplication by tables are to be found in § 3, art. 1.

It is almost unnecessary to remark that a table of squares may be used instead of one of quarter squares if the semisum and semidifference of the numbers to be multiplied be taken as factors. Tables of squares and cubes are described in the next section.

***Voisin,** 1817. Quarter squares of numbers from unity to 20,000. We have taken the title from the introduction to Mr. Laundy's 'Quarter Squares' (1856). De Morgan also so describes the work. We have seen no copy; but there is one in the Graves Library, although we were unable to find it: it will be described from inspection in the supplement to this Report.

Leslie, 1820. On pp. 249–256 there is a table of quarter squares of numbers from 1 to 2000, reprinted from Voisin, 1817, whose work Leslie met with at Paris in 1819. There is also given, facing p. 208, a large folding sheet, containing an enlarged multiplication table, exhibiting products from 11×11 to 99×99, the table being of triangular form. There are also, on the same sheet, two smaller tables, the first giving squares, cubes, square roots (to seven places), cube roots (to six places), and reciprocals (to seven places) of numbers from 1 to 100, and the second being a small multiplication table from 2×2 to 25×25. In the first edition (1817, pp. 240) the quarter-square table does not appear; and in the folding sheet (which follows the

preface) the smaller multiplication table is not added; squares and cubes only are given in the other small table.

Centnerschwer, 1825. [T. I.] A table of quarter squares to 20,000; viz. $\frac{x^2}{4}$, is tabulated from $x=1$ to $x=20,000$, the fraction $\frac{1}{4}$, which occurs when x is odd, being omitted. The last two figures of the quarter square, which only depend on the last two figures of the number, are given once for all on two slips bound up to face pp. 2 & 41.

Full rules are given as to how to use the table as a table of squares; and three small tables are added, by means of which the square of any number of *five figures* can be found tolerably easily. The arguments are printed in red.

[T. II.] Square roots of numbers from 1 to 1000 to six places.

There is a long and full introduction prefixed.

In his preface Centnerschwer states that after his work was in the press, he received from Crelle a table, by J. A. P. Bürger, entitled "Tafeln zur Erleichterung in Rechnungen," Karlsruhe, 1817, in which the author claims to be inventor of the method, while Centnerschwer states it was known to Ludolf (1690), and even Euclid. That Ludolf was the inventor of the method is true; and there is attached to his work a table of squares to 100,000 (see Ludolf, § 3, art. 4).

The full title of Bürger's work, which we have not been successful in obtaining a sight of, is (after Rogg) as follows:—"Tafeln zur Erleichterung in Rechnungen fur den allgemeinen Gebrauch eingerichtet. Deren ausserst einfach gegebene Regeln, nach welchen man das Product zweier Zahlen ohne Multiplication finden, auch sie sehr vortheilhaft bei Ausziehung der Quadrat- und Cubicwurzel anwenden kann, sich auf den binomischen Lehrsatz grunden. Nebst Anhang uber meine im vorigen Jahr erschienene Paralleltheorie. Carlsruhe, 1817. 4to." The book last referred to was entitled "Vollständige Theorie der Parallellinien &c. Carlsruhe, 1817; 2nd edit. 1821," as given by Rogg under *Elementar-Geometrie*.

Merpaut, 1832. The *première partie* gives the *arithnome* (*i. e.* quarter square) of all numbers from 1 to 40,000, so arranged that the first three figures of the argument are sought at the head of the table, the fourth figure at the head of one of the vertical columns, in which, in the line with the final (fifth) figure in the left-hand column, is given the quarter square required. The quarter squares are printed in groups of three figures, the second group being under the first, &c. A specimen of this table is given by Laundy (1856, p. v of his Introduction).

The *deuxième partie* gives the reciprocals of all numbers from 1 to 10,000 to nine figures.

The author seems not to have been aware of the existence of any of the previous works on the subject of quarter squares.

Laundy, 1856. Quarter squares of all numbers from unity to 100,000, the fraction $\frac{1}{4}$, which occurs when the number is odd, being, as usual, omitted. The arrangement is as in a seven-figure logarithm table; viz. the first four figures are found in the left-hand column, and the fifth in the top row; the three or four figures common to the block of figures are also separated as in logarithmic tables, and the change in the fourth or fifth figure is denoted by an asterisk prefixed to all the quarter squares affected: at the extreme left of each page is a column of corresponding degrees, minutes, and seconds (thus, corresponding to 43510 we have $12° 5' 10''=43510''$). At the bottom of the page are differences (contracted by the omission of the last two figures)

and proportional parts. The figures are very clear; and there is a full introduction, with explanations of the use, &c. of the tables.

Mr. Laundy was induced to construct his table by Prof. Sylvester's paper in vol. iv. of the 'Assurance Magazine,' referred to above; and a description of the mode of construction &c. of the table (most of which is also incorporated in the introduction to it) is given in vol. vi. of the 'Assurance Magazine.'

Art. 4. *Tables of Squares, Cubes, Square roots, and Cube roots.*

Tables of squares (or square roots of square numbers) are of nearly as great antiquity as multiplication tables, and would, we think, be found to be rather common in early manuscripts on arithmetic. They are, as a rule, but slightly noticed in histories of the subject (see references in § 3, art. 1), partly because the latter are very meagre, and very many manuscripts remain still unexamined, and partly because it is rather the province of a history to describe the improvement of processes. The perfection of the methods of extracting the square root of numbers not complete squares, however, occupies a conspicuous place.

In the MSS. Gg. ii. 33 of the Cambridge University Library, are two fragments, one of Theodorus Meletiniotes, the second of Isaac Argyrus (both much of the same date, time of John Palæologus, 1360) (concerning the first, see *Vincent*, Manuscrit de la Bibliothèque Impériale, xix. pt. 2. p. 6). The fragment is a portion of the first book, and contains rules and small tables for multiplication, fractional computation &c.

The tract of Isaac Argyrus is entitled "*τοῦ 'Αργύρου εὕρεσις τῶν τετραγωνικῶν πλευρῶν τῶν μὴ ῥητῶν ἀριθμῶν.*"

At the end there is a table of the square roots of all integral numbers from 1 to 120, in sexagesimal notation. The table is prepared as if for three places of sexagesimals; but usually two only are perfect. Errors (probably due to the copyist) are frequent. Before the table is a description of the method of its use, including an explanation of the method of proportional parts.

De Morgan speaks of two early (printed) tables in Pacioli's 'Summa,' 1494, and by Cosmo Bartoli, 1564, extending respectively to the squares of 100 and 661. The tables which we have examined are described below; but there are several of some extent, which De Morgan refers to, that we have not seen, viz.:—Guldinus, 1635, squares and cubes to those of 10,000; W. Hunt, 1687, squares to that of 10,000; and J. P. Büchner's 'Tabula Radicum,' Nuremberg, 1701, which gives squares and cubes up to that of 12,000 (full title given in Rogg). Lambert (Introd. ad Suppl. &c. 1798) says that Büchner's table is "plena errorum." Rogg gives the title "Böbert, K. W., Tafeln der Quadratzahlen aller natürlichen Zahlen von 1–25,200; der Kubikzahlen von 1–1200; der Quadrat- u. Cubicwurzeln von 1–1000. Neu berechnet, Leipzig, 1812;" and the title occurs in the Roy. Soc. Lib. Cat. (though the book is not to be found in the Library). De Morgan mentions "Schiert, 'Tafeln,' &c. Rohn om Rheim, 1827," as giving squares to 10,000, which is no doubt a misprint for "Schiereck, J. F., Tafeln aller Quadrate von 1 bis 10,000. 4to. Köln am Rhein, 1827," which occurs in the Babbage Catalogue, and also in Rogg. From the title of another work of Schiereck's given in the former catalogue, it appears that the table of squares also appeared as an appendix to his 'Handbuch für Geometer,' published in the same year.

De Morgan speaks of Ludolf's 'Tetragonometria,' 1690, which gives squares up to that of 100,000, "as being the largest in existence, and very

little known." This is true; but KULIK, 1848, is of the same extent, and also gives *cubes up to that of* 100,000, thus giving the largest table of squares, and by far the largest table of cubes in the same work, and in a compact and convenient form: of this work also it may be said that it is very little known.

HUTTON, 1781 (§ 4), gives squares to that of 25,400, and cubes to that of 10,000; but for most purposes BARLOW (stereo. 1840), which gives squares, cubes, and square roots and cube roots (and reciprocals) of numbers to 1000, and is very accurate, is the best. We have not seen any square-root or cube-root table of greater extent.

Extensive tables of quarter squares have been published, which are described in § 3, art. 3; and some tables of squares, as FAÀ DE BRUNO, were constructed with the view of being used in applying the method of least squares.

It is scarcely necessary to remark that logarithms find one of the most valuable applications in the extraction of roots. Multiplications &c. can be performed generally without their aid with a little more trouble; for finding square and cube roots they are extremely useful; but for the extraction of higher roots there exists no other method admitting of convenient application.

Maginus, 1592. The 'Tabula Tetragonica' is introduced by the words "sequitur tabula numerorum quadratorum cum suis radicibus nunc primum ab auctore supputata, ac in lucem ædita," and occupies leaves 41–64. It gives the squares of all numbers from 1 to 100,100. We have seen the 'Tabula Tetragonica' quoted as an independent work; and De Morgan says that it was published separately, with headings and explanations in Italian instead of Latin. In the copy before us *Tavola* is misprinted for *Tabula* on pp. 41 and 43 back (only the leaves are numbered).

The work contains sines, tangents, and secants also.

Magini was, we suppose, the vernacular name of the author, and Maginus the same Latinized. We have somewhere seen Magini and Maginus spoken of as if they were different persons.

Alstedius, 1649. In part 3. pp. 254–260, Alsted gives a table of squares and cubes of numbers from 1 to 1000. Alsted's is the first Cyclopædia, in the sense that we now understand the word.

[**Moore, Sir Jonas,** 1650?] Squares and cubes of numbers from 1 to 1000, fourth powers from 1 to 300, fifth and sixth powers from 1 to 200.

In the book before us (Brit. Mus.) this tract (which has a separate pagination) is bound up at the end, after Moore's 'Arithmetick (and Algebra), Contemplationes Geometricæ, and Conical Sections.' De Morgan says that power tables, exactly the same as these, were given in Jonas Moore's 'Arithmetic' of 1650, and reprinted in the edition of 1660; so that probably the tract noticed here usually formed part of the 'Arithmetick.'

[**Pell**], 1672. Squares of numbers from 1 to 10,000 (pp. 29). This is followed by the 6 one-figure endings, the 22 two-figure endings, the 159 three-figure endings, and the 1044 four-figure endings, which square numbers admit of. They are given at length, and also in a synoptical form. The last page in the Roy. Soc. copy is signed John Pell. (In the Royal Society's Library Catalogue this table is entered under *Fell,* the signature at the end in the Society's copy having been struck out so as to render the first letter uncertain.)

In the Brit. Mus. is a copy without any name (so that perhaps Pell's name was supplied in the Roy. Soc. copy only in manuscript). 'Dr. Pell's Tables,' however, is written in it, and no doubt can exist about its authorship,

Ludolf, 1690. Squares of all numbers from unity to 100,000, arranged in columns, so that the first three or four figures of the root are to be found at the top of the column, while the final ones are given in the left-hand column of the page. The table is well printed and clear, and, except Kulik, 1848, which is of the same extent, is the largest table of squares that has been published, and occupies about 420 pages. Some errata in it are given at the end of the introduction (150 pp. in length), in which all possible uses of the table are explained.

Lambert (Introd. ad Supplementa, 1798) speaks of the numbers in the table as "satis accurati." In chapter v. (pp. 48–86) ('De Tabularum usu seu Praxi circa Multiplicationem et Divisionem') the use of the table as one of quarter squares (see § 3, art. 3) is fully explained; as squares are given in the table, the sum and difference have to be divided by 2. Rules and examples are also added as to how to proceed when the semisum exceeds the limits of the table by any amount; and the processes &c. are explained with such fulness as to prove that all the credit of first perceiving the utility of the method and calculating the necessary table is due to Ludolf.

The work is said to be very scarce; but we have seen several copies; there is one in the Library of Trinity College, Cambridge, and another in the Graves Library.

Heilbronner (under Herwart ab Hohenburg) mentions Ludolf (Hist. Math. p. 827), and (referring doubtless to the method of quarter squares) says that he invented a method of performing multiplications and divisions without the Pythagoræan abacus, "quæ prolixe ab Illustr. Wolfio in seinen Anfangs-Gründen et suis Elementis Matheseos exponitur."

Séguin, 1786. At the end of the book is given a table of the squares and cubes of numbers from unity to 10,000. The figures have heads and tails, and are very clear. De Morgan states that the table was reprinted at about the beginning of the century, and that it was this table which convinced him of the superiority of the numerals with heads and tails, and led him in the reprint of Lalande's table, 1839, to adopt this figure—an example which has since been very frequently followed.

As De Morgan does not appear to have seen it, it is *possible* that the original table was not reprinted, but only published separately, as the figures in the table attached to Séguin answer De Morgan's description very well.

Barlow's tables (the stereotyped edition of 1840). Squares, cubes, square roots, cube roots, and reciprocals to 10,000. The square roots and cube roots are to seven places, and the reciprocals to seven significant figures, viz. nine places to 1000, and above this ten. The work is a reprint of the more important tables in Barlow, 1814 (described in § 4); it was suggested by De Morgan, who wrote the preface (2 pp.), and edited by Mr. Farley, of the Nautical-Almanac Office, who also examined carefully Barlow's tables. A list of ninety errors found in the latter is given on the page following the preface. This reprint is, we believe, very nearly, if not quite, free from error; it is clearly printed and much used. We have also an edition, 1866, from the plates of 1840.

Kulik, 1848. The principal table occupies pp. 1–401, and gives the squares and cubes of all numbers *from* 1 *to* 100,000. There is a compression resembling that in Crelle's 'Rechentafeln;' viz. the last four figures of the square and cube are printed but once in each line, these figures being the same for all squares and cubes in the same line across the double page. The arrangement will be rendered clear by the description of a page—say, that corresponding to 92. There are ten columns headed 92, 192, 292. . . . , 992,

each containing two vertical rows of numbers, the one corresponding to N^2, and the other to N^3; the lines are numbered 0, 1, 2....49 (and on the next double page 50....99). If, then, we wish to find the cube of 79217, we take the figures 497113061 31 from column 792, line 17, and add the last four figures 1313 (which conclude the cube of 9217 in the same line); so that the cube required is 497113061311313. Certain figures, common to the whole or part of a column, are printed at the top, and the change in the column is denoted by an asterisk. This is the largest table of cubes in existence, and (except LUDOLF, which is of the same extent) is also the largest table of squares. The printing is clear, and the book not bulky; so that the table can be readily used. At the end are eleven subsidiary tables. T. 1 (*Perioden gerader Summenden*) consists of columns marked 4, 6, 8....48 at the top, and 96, 94....52 at the bottom, each containing the "complete period" of the number in question; thus for 42 we have 42, 84, 26, 68, 10, &c. (these numbers being the last two figures of a series of terms in arithmetical progression, 42 being the common difference); and these are given till the period is completed, *i. e.* till 42 occurs again. This may be at the end of 25 or 50 additions; if the former, the periods are given commencing with 1, 2, 3 (as well as 0); if the latter, with 1 or 2 only, as the case may be; the periods for x and $100-x$ are of course the same, only in reverse order. The use of the table as a means of verifying the table of squares is obvious.

T. 2. Primes which are the sum of two squares (these being given also) up to 10,529.

T. 3. Odd numbers which are the difference of two cubes (these being given also) to 12,097.

T. 4. Odd numbers which are the sum of two cubes (these being given also) to 18,907.

T. 5–9. Four-figure additive and subtractive congruent endings for numbers ending in 3 and 7, or 1 and 9, &c.: the more detailed description of these tables belongs to the theory of numbers, which will form a part of a subsequent Report.

T. 10. The 1044 four-figure endings for squares, and the figures in which the corresponding numbers must end.

T. 11. First hundred multiples of π and π^{-1} to twelve places. There is appended to the tables a very full description of their object and use.

Bruno, Faà de, 1869. T. I. of this work (pp. 28) contains squares of numbers from 0·000 to 12·000, at intervals of ·001 to four places (stereotyped), intended for use in connexion with the method of least squares.

The following are references to § 4:—

Tables of Squares and Cubes, or both Squares and Cubes.—SCHULZE, 1778 [T. IX.] and [T. X.]; HUTTON, 1781 [T. II.] and [T. III.]; VEGA, 1797, Vol. II. T. IV.; LAMBERT, 1798, T. XXXV. and XXXVI.; BARLOW, 1814, T. I.; SCHMIDT, 1821 [T. V.] (with subsidiary tables); HANTSCHL, 1827, T. VIII.; *SALOMON, 1827, T. I.; GRUSON, 1832, T. II. and III.; HÜLSSE'S VEGA, 1840, T. IX. C.; TROTTER, 1841 [T. VI.]; MULLER, 1844 [T. III.]; MINSINGER, 1845 [T. II.]; KÖHLER, 1848, T. V. and VI.; WILLICH, 1853, T. XXI.; BEARDMORE, 1862, T. 35; RANKINE, 1866, T. I. and II.; WACKERBARTH, 1867, T. VI.; PARKHURST, 1871, T. XXVI. and XXXII., and XXXIV. (multiples of squares); PETERS, 1871 [T. VI.]. See also TAYLOR, 1780 [T. IV.] (§ 3, art. 9).

Tables of Square Roots and Cube Roots.—DODSON, 1747, T. XIX.; SCHULZE, 1778 [T. XI.] and [T. XII.]; MASERES, 1795 (two tables);

VEGA, 1797, Vol. II. T. IV.; HANTSCHL, 1827, T. VIII.; *SALOMON, 1827, T. I.; GRUSON, 1832, T. IV. and V.; HÜLSSE'S VEGA, 1840, T. VIII.; TROTTER, 1841 [T. VI.]; MINSINGER, 1845 [T. II.]; KÖHLER, 1848, T. VII.; WILLICH, 1853, T. XXI.; BEARDMORE, 1862, T. 35; *SCHLÖMILCH [1865?]; RANKINE, 1866, T. I. A; WACKERBARTH, 1867, T. VII. See also CENTNERSCHWER, 1825 [T. II.] (§ 3, art. 3). And for *Squares* (for method of least squares), MULLER, 1844 [T. III.].

Endings of Squares.—(Three-figure endings) LAMBERT, 1798, T. IV.

Art. 5. *Tables of Powers higher than Cubes.*

We know of no work containing powers of numbers (except squares and cubes) only. Both HUTTON, 1781, and BARLOW, 1814, give the first ten powers of the first hundred numbers; but we have seen no more extensive table of this kind. SHANKS (§ 4) gives every twelfth power of 2 as far as 2^{721}; and, according to De Morgan, John Hill's 'Arithmetic,' 1745, has all powers of 2 up to 2^{144}. Tables of compound interest are, in fact, merely power tables, as the amount of £M at the end of n years at r per cent. is $M\left(1+\frac{r}{100}\right)^n$. In interest tables r has usually values from 1 to 8 or 10 at intervals of $\frac{1}{2}$ or $\frac{1}{4}$ for different periods of years; but they could not be of much use, except for the purpose for which they are calculated.

A good table of powers is still a desideratum, as the need for it is often felt in mathematical calculations. Very many functions are expansible in an ascending (convergent) series of the form $A_0+A_1x+A_2x^2+$ &c., and a descending series (generally semiconvergent) of the form $B_0+B_1x^{-1}+B_2x^{-2}+$ &c. The former is usually very convenient for calculation when x is small, and the latter when x is large; but between the two, for values of x included between certain limits above unity, there will be an interval where neither series is suitable—the ascending series because the terms $x, x^2, \ldots$ ($x>1$) increase so fast that n must be taken very large (*i. e.* very many terms must be included) before A_n is so small that A_nx^n can be neglected, and the descending series because it begins to diverge before it has yielded as many decimals as are required. For these intermediate values the former series (if there is no continued fraction available) must be used; and then the terms begin by increasing, often so rapidly, if x be moderately large, that it may be necessary to calculate some of them to fifteen or twenty figures to obtain a correct value for the function to only seven or eight decimals. In these cases, so long as ten figures only are wanted, logarithms are employed; but when more are required recourse must be had to simple arithmetic; and it is then that a power table is so much needed. Mr. J. W. L. Glaisher has had formed in duplicate a table giving the first twelve powers of the first thousand numbers, which, after the calculation has been made independently a third time, will be stereotyped and published, probably in the course of 1873; it is hoped that it will help to make the tabulation of mathematical functions somewhat less laborious and difficult.

The following tables on the subject of this article are described in § 4:—

Tables of Powers higher than Cubes.—DODSON, 1747, T. XXI. (powers of 2) and T. XXII.; SCHULZE, 1778 [T. VIII.]; HUTTON, 1781 [T. IV.]; VEGA, 1797, Vol. II. T. II. (powers of 2, 3, and 5); VEGA, 1797, Vol. II. T. IV.; LAMBERT, 1798, T. VII.–IX. (powers of 2, 3, and 5) and T. XI.; BARLOW, 1814, T. II. and III.; HULSSE'S VEGA, 1840, T. VI. (powers of 2, 3, 5) and T. IX. A, B, D, E; KÖHLER, 1848, T. II. (powers of 2, 3, and 5) and T. IV.; SHANKS, 1853 (powers of 2 to 2^{721}); BEARDMORE, 1862, T. 35;

RANKINE, 1866, T. 2. See also Sir JONAS MOORE [1650?], § 3, art. 4; TAYLOR, 1781 [T. IV.] (§ 3, art. 9).

Tables for the solution of Cubic Equations, viz. $\pm(x-x^3)$.—LAMBERT, 1798, T. XXIX.; BARLOW, 1814, T. IV.

Art. 6. *Tables for the expression of vulgar fractions as decimals.*

The only separate tables we have seen are WUCHERER and GOODWYN'S works described at length below. The Babbage Catalogue contains the title of an anonymous book, "Tafeln zur Verwandlung aller Brüche von $\frac{1}{100}$ bis $\frac{100000}{100}$, und von $\frac{1}{1000}$ bis $\frac{100}{1000000}$ in fünf- bis siebenziffrige Decimalbrüche, 4to, Oldenburg, 1842," of which De Morgan says "it gives every fraction less than unity whose denominator does not exceed three figures, nor its numerator two, to seven places of decimals. It is arranged by numerators; that is, all fractions of one numerator are upon one double page." Reciprocals would properly be included in this article; but from their more frequent use they have been placed in an article by themselves (§ 3, art. 7); PICARTE'S table in that article gives multiples of reciprocals.

We must especially mention the "Tafel zur Verwandlung gemeiner Brüche mit Nennern aus dem ersten Tausend in Decimalbruche," which occupies pp. 412–434 of vol. ii. of 'Carl Friedrich Gauss Werke,' Göttingen, 4to, 1863, and which somewhat resembles GOODWYN'S tables described below. In it, among other things, the reciprocal of every prime less than 1000 is given *completely* (*i. e.* till the figures circulate). Had we met with the table earlier we should have given a full description; but we merely confine ourselves here to giving the reference, reserving a more detailed explanation for a future Report.

Wucherer, 1796. The decimal fractions (to five places) for all vulgar fractions, whose numerators and denominators are both less than 50 and prime to one another, arranged according to denominators; so that all having the same denominator are given together: thus the order is.... $\frac{1}{17}$, $\frac{2}{17}$, $\frac{3}{17}$, ... $\frac{16}{17}$, $\frac{1}{18}$, $\frac{5}{18}$ ...., the arguments being only given in their lowest terms. After $\frac{48}{49}$ the system is changed, and the decimals are given for vulgar fractions whose numerators are less than 11 only; thus we have $\frac{1}{50}$, $\frac{2}{50}$, $\frac{3}{50}$ .... $\frac{10}{50}$, $\frac{1}{51}$, $\frac{2}{51}$ .... as consecutive arguments (the arguments not being necessarily in their lowest terms); and the denominators proceed from 50 to 999.

[T. II.]. *Sexagesimal-Brüche*, viz. sexagesimal multiplication table to 60 × 60; thus, as 5 × 29″ = 145″ = 2′ 25″, the table gives 2.25 as the tabular result for the joint-entry 5 and 29. There are seven other tables (II.–VIII.) for the conversion of money into decimals of other money, for the coins of different countries; the English table will serve as an example. There are given as arguments $\frac{1}{240}$, $\frac{2}{240}$, $\frac{3}{240}$ .... $\frac{239}{240}$ (*i. e.* 1*d.*, 2*d.*, 3*d.*, &c.), and as tabular results the corresponding decimal fraction to ten places (*i. e.* of £1), and also the shillings and pence; thus for $\frac{73}{240}$ there are given ·3041666666, and 6*s.* 1*d.*

The *Reichs-Geld* and *Pfennig* table is practically the same; the denominators are in all cases 240, or 960, or submultiples of the latter. Regarded mathematically the English table gives nearly as much as all the rest, as for denominators above 240 only a few numerators are taken. There are also tables of interest, present value, &c., to a great many places. The value of π is given on the last page to 306 places; thus, if the diameter = 10000....(306 ciphers), then π = 31415 (307 figures), the ciphers and figures being written

at length—a curious mode of statement at the end of a book occupied with decimal fractions.

Goodwyn's Tables, 1816–1823. It is convenient to describe Goodwyn's four works (the titles of which are given at length in § 5) together, as they all relate to the same subject.

The *Tabular Series of Decimal Quotients* (1823) forms a handsome table of 153 pages, and gives to eight places the decimal corresponding to every vulgar fraction less than $\frac{99}{991}$, whose numerator and denominator are both not greater than 1000. The arguments are not arranged according to their numerators or denominators, but according to their magnitude, so that the tabular results exhibit a steady increase from ·001 ($=\frac{1}{1000}$) to ·09989909 ($=\frac{99}{991}$). The author intended the table to include all fractions whose numerators and denominators were both less than 1000 without restriction; and at the end of the book is printed "End of Part I.;" but no more was ever published.

The arrangement of the arguments in order of magnitude is not very good, as it requires the first two figures of the decimal to be known in order to know where to look for it in the table; the table would be more useful if it were required to find a vulgar fraction (with not more than three figures in numerator or denominator) nearly equal to a given decimal*; but this is not a transformation that is often wanted. When the decimal circulates and its period is completed within the first eight figures, points are placed over the first and last figures of the period, if not, of course only over the first; and by means of the same author's table of 'Circles' described below, the period can be easily completed, and the whole decimal fraction found. The fractions which form the arguments are given in their lowest terms.

The *Table of Circles* (1823) gives all the periods of the circulating decimals that can arise from the division of any integer by another integer less than 1024. Thus for 13 we find $\cdot\dot{0}7692\dot{3}$ and $\cdot\dot{1}5384\dot{6}$, which are the only periods in which the fraction $\frac{x}{13}$ can circulate.

The periods for denominator $2^n\,5^m\,x$ are evidently the same as those for denominator x; and arguments of this form are therefore omitted; but a table is given at the end (pp. 110 and 111), showing whether for any denominator less than 1024 the decimal (1) terminates, and is therefore not included in the table, (2) is in the table as it stands, or (3) is in the table but has to be sought under a different argument (these last being numbers of the form $2^n\,5^m\,x$). A third table (p. 112) also gives the number of places after the *separatrix* (decimal point) at which the period commences.

The principal table occupies 107 pp. Some of the numbers are very long, (*e.g.*, for 1021 there are 1020 figures in the period), and are printed in lines of different lengths, giving a very odd appearance to many of the pages†.

A table at the end contains all numbers of the form $2^n\,5^m$ that are less than

* It is proper to note, however, that the table was no doubt calculated for this purpose; the author considered his 'Table of Circles' as giving decimals to vulgar fractions, and intended this table to give vulgar fractions to decimals (see the introduction to the second part of the 'Centenary' 1816); the 'Tabular Series' (1816) is complementary to the 'Centenary;' but not so the 'Tabular Series' (1823) to the 'Table of Circles' (1823), as the latter only gives the periods.

† If the period of a decimal consists of an even number of figures, it is well known that the figures in the last half are the *complements to nine* of the figures in the first half; and the periods have been printed so that the complementary figures should be under one another. When the period is odd, there is always another period of complementary figures, and the two are printed one under the other; these facts account for what at first sight appears a capricious arrangement of the figures.

1,000,000, arranged in order of magnitude, with the values of n and m, and also the values of the reciprocals of the numbers (expressed as decimals) and the total number of the proper vulgar fractions in their lowest terms which can arise for any of the arguments as denominator. An example of the use of the tables is given at the end of the book.

The *First Centenary &c.* [1816] contains the factors of all numbers to 100, and the complete periods of their reciprocals or multiples of their reciprocals, also the first six figures of every decimal fraction equivalent to a vulgar fraction whose denominator is equal to the argument. The following is a specimen of one of the tables:

	34	
	2.17	
	·70588235	
	29411764	
33	$\cdot 9\dot{7}0588$	1
31	$\cdot 9\dot{1}1764$	3
29	·852941	5
27	$\cdot 7\dot{9}4117$	7
25	$\cdot 7\dot{3}5294$	9
23	$\cdot 6\dot{7}6470$	11
21	$\cdot 6\dot{1}7647$	13
19	$\cdot 5\dot{5}8823$	15

The explanation is very simple: we have $\frac{33}{34} = \cdot 9\dot{7}0588$, and the other figures of the period are $235294117 6\dot{4}$; $\frac{31}{34} = \cdot 9\dot{1}1764$, and the other figures are $7058823529\dot{4}$, &c. If the numerator is in the third column we take the complement of the result (*i. e.* subtract each figure from 9): thus $\frac{1}{34} = \cdot 0\dot{2}9411$, and the other figures of the period are $7647058823\dot{5}$. The even numbers are omitted, as the fractions are not in their lowest terms; thus $\frac{32}{34} = \frac{16}{17}$, and must be sought under argument 17. [This table was published separately by Goodwyn for private circulation. There is no date on the titlepage*; but the address is written from Blackheath, and dated March 5, 1816.] There is added a tabular series of complete decimal quotients of fractions whose numerator is not greater than 50 and denominater not greater than 100 (the heading of the table incorrectly says, "neither numerator nor denominator greater than 100"), arranged as in the 'Tabular Series' &c., 1823; it is followed by an auxiliary table for completing such quotients as consist of too many places to allow all the digits of their periods to appear in the principal table. There is an appendix on Circulates &c. The 'Tabular Series' (1816 and 1823) are interesting as exhibiting in the order of magnitude all fractions whose numerators and denominators are both less than 100 up to $\frac{1}{2}$, and whose numerators and denominators are both less than 1000 up to $\frac{99}{991}$. In the preface to the latter table the author gives as a fact he has observed, that

* It is by no means improbable that the titlepage has been torn out from the only copy we have seen, viz. that in the Royal Society's Library.

"In any three consecutive vulgar fractions in the table, if the numerators of the extremes and the denominators be added together, the sum will form the numerator and denominator of a fraction equal to the mean." That this is the case with all fractions, ranged in order, whose numerators and denominators are integers less than given integers, is a theorem discovered by Cauchy and published by him in his 'Exercices.'

It has been thought worth while to describe Goodwyn's works at some length, as they are almost unique of their kind, and are rarely to be met with.

De Morgan states that "Mr. Goodwyn's manuscripts, an enormous mass of similar calculations, came into the possession of Dr. Olinthus Gregory, and were purchased by the Royal Society at the sale of his books in 1842." There is no mention of them, however, in the Royal Society's Catalogue of MSS.; and nothing is known of them at the Society. They may possibly be brought to light in the rearrangement of the manuscripts consequent upon the approaching change of rooms.

Art. 7. *Tables of Reciprocals.*

The most extensive table is

Oakes, 1865. Reciprocals from 1 to 100,000. This table gives seven figures of the reciprocal, and is arranged as in tables of seven-figure logarithms: viz. the first four figures are found in the column at the left-hand side of the page, the fifth figures run along the top line, and the sixth and seventh are interpolated for by proportional parts. The reciprocal of a number of five figures is therefore taken out at once, and the process of taking out a reciprocal is exactly similar to that of taking out a logarithm.

From 10,000 to 22,500 the differences and proportional parts (being numerous) are placed on the lower half of the page, the differences being also placed at the side of each line; but above 22,500 the differences and proportional parts are placed at the side of the page as in tables of logarithms. The figures have heads and tails; and the change in the third figure of the reciprocal is made evident by prefixing an asterisk to the succeeding numbers in the line. The table is the result of an original calculation, and was constructed by means of the obvious theorem that the difference of two reciprocals, divided by the difference of the corresponding numbers, is the reciprocal of the product of those numbers. The reciprocals of the higher numbers, however, were calculated by differences, which differences were found by logarithms. Various checks were applied; and the whole was virtually recomputed on the Arithmometer of M. Thomas de Colmar. The significant figures of the reciprocals alone are tabulated, decimal points and ciphers being omitted, for the same reason that characteristics are left out in logarithmic tables.

In T. I. of Barlow (§ 4) reciprocals are given of numbers from 1 to 10,000; and this table also appears in the stereotype reprint of 1840 (see § 3, art. 4): the latter is the most generally used table of reciprocals, and is of sufficient extent for most purposes; it is also reputed to be very accurate, and is perhaps free from error.

It must be added that Goodwyn's 'Table of Circles,' and 'Tabular Series,' &c., 1823 (§ 3, art. 6), give reciprocals of numbers less than 1024 complete; viz. the whole period is given, even where it exceeds a thousand figures.

See also the reference to Gauss, vol. ii., near the beginning of the last article (§ 3, art. 6).

As most nearly connected with a table of reciprocals (it gives not only

the reciprocals, but also multiples of them), we here describe PICARTE's 'La Division réduite à une Addition.'

Picarte [1861]. The principal table occupies pp. 15–104, and gives, to ten significant figures, the reciprocals of all numbers from 1000 to 10,000, and also the first nine multiples of the latter (which are therefore given to 10 or 11 significant figures). It is easy to see how this table reduces Division to Addition. The arguments run down the left-hand column of the page; and there are nine other columns for the multiples; each page contains 100 lines; so that there are 10,300 figures to the page. Owing, however, to its size, and to the smallness and clearness of the figures, there is no confusion, the lines being well leaded. The great table is preceded by two smaller ones, the first of which (pp. 6, 7) gives the figures from the ninth to the fourteenth (inclusive) of the logarithms of the numbers from 101,000 to 100,409 at intervals of unity (downwards), with first, second, and third differences; and the second (pp. 10, 11) gives ten-figure logarithms of numbers to 1000; and from 100,000 to 101,000 at intervals of unity (with differences). There is also some explanation &c. about the manner of calculating logarithms by interpolation, &c. The author remarks on the increasing rarity of ten-figure tables of logarithms, referring, of course, to VLACQ and VEGA. The whole work was submitted by its author to the French Academy, and reported on favourably by a Committee consisting of MM. Mathieu, Hermite, and Bienaymé. The report (made to the Academy Feb. 14, 1859) is printed at the beginning of the work. M. Ramon Picarte describes himself as Member of the University of Chili; and the Chilian Government subscribed for 300 copies of the work. There is no date; but the "privilége" is dated Nov. 1860, and the book was received at the British Museum, April 29, 1861, so that the date we have assigned is no doubt correct. On the cover of the book are advertised the following tables by the same author, which we have not seen:—

"Tables de multiplication, contenant les produits par 1, 2, 3. . . . 9 et toutes les quantités au-dessous de 10,000, 1 vol. in-18 jésus."

"Tableau Pithagorique, étendu jusqu'à 100 par 100, sous une nouvelle forme qui a permis de supprimer la moitié des produits."

It is scarcely necessary to remark that any trigonometrical table giving sines and cosecants, cosines and secants, or tangents and cotangents, may be used (and sometimes with advantage) as a table of reciprocals. The extreme facility with which reciprocals can be found by logarithms has prevented tables of the former from being used or appreciated as much as they deserve.

The following is the list of references to § 4:—

Tables of Reciprocals.—MASERES, 1795; BARLOW, 1814, T. I. (to 10,000); TROTTER, 1841 [T. VIII.]; WILLICH, 1853, T. XXI.; BEARDMORE, 1862, T. 35; SCHLÖMILCH [1865?]; RANKINE, 1866, T. I. and I. A; WACKERBARTH, 1867, T. IX.; PARKHURST, 1871, T. XXV.; see also MERPAUT, 1832 (§ 3, art. 3); BARLOW (1840) (§ 3, art. 4).

Art. 8. *Tables of Divisors (Factor tables), and Tables of Primes.*

If a number is given, and it is required to determine whether it be prime, and if not what are its factors, there is no other way of effecting this except by the simple and laborious process of dividing it by every prime less than its square root, or until one is found that divides it without remainder*. The construction of a table of divisors is on the other hand very simple, as it

* Wilson's theorem (viz. that $1 \cdot 2 \cdot 3 \ldots (n-1) + 1$ is or is not divisible by n, according as n is or is not prime) theoretically affords a criterion; but the labour of applying it would be far greater than the direct procedure by trial.

is merely necessary to form the multiples of 2, 3, 5.. up to the extent of the table, the numbers that do not occur being of course primes. The manner in which the formation of these multiples is best effected, and other practical details, are explained by BURCKHARDT in his preface to the second million. The following is a list of tables of divisors and of primes, abridged from an elaborate account prefixed to CHERNAC:—

1657. Francis Schooten: table of primes to 9997.

1668. Pell (in Branker's translation of Rhonius's 'Algebra,' published at London): least divisors of odd numbers not ending in 5 to 100,000.

1728. Poetius. An 'anatome' of numbers to 10,000.

1746. KRÜGER. Primes to 100,999.

1767. Anjema. All divisors (simple and compound) of numbers to 10,000.

1770. LAMBERT. Least divisors of numbers to 102,000 (multiples of 2, 3, and 5 omitted).

1772. Marci. Extension of Lambert's table by the addition of primes to 400,000.

1785. Neumann. Simple divisors (Pell only gave the least) of numbers to 100,100 (multiples of 2, 3, 5 omitted).

1797. VEGA. Simple factors to 102,000, and primes to 400,000 (see VEGA, 'Tabulæ,' 1797, Vol. II. T. I.).

1804. Krause. Factor table to 100,000.

From the above list Chernac has omitted RAHN (1659), giving factors to 24,000, and PIGRI (1758) to 10,000, which are described below. A more important omission is that of FELKEL, whose table is noticed at length further on.

The titles of Anjema's, Neumann's, and Krause's works are given in the Babbage Catalogue as follows:—"Anjema (Henricus), Tabula divisorum omnium numerorum naturalium ab 1 usque ad 10000. 4to, Lugd. Bat. 1767;" "Neumann (Johann), Tabellen der Prim-Zahlen und der Factoren der Zahlen, welche unter 100100, und durch 2, 3, oder 5 nicht theilbar sind; herausgegeben durch J. N. 4to, Dessau, 1785;" and "Krause (Karl C. F.), Factoren- und Primzahlen-Tafel von 1 bis 100000 neu berechnet. Fol. Leipzig, 1804."

The same catalogue also contains the title, "Snell (F. W. D.), Ueber eine neue und bequeme Art, die Faktorentafeln einzurichten, nebst einer Kupfertafel der einfachen Faktoren von 1 bis 30000. 4to. Giessen und Darmstadt, 1800."

The following are accounts of tables we have seen:—

Rahn, 1659. On pp. 37–48 is given a table of divisors; viz. the least divisor of every number, not divisible by 2 or 5, is tabulated from 1 to 24,000, the primes being marked with a *p*.

Pigri, 1758. All the simple factors (so that if multiplied together they give the number) are given of all numbers from 1 to 10,000. When the number is a power, letters are used instead of numbers ($a = 2$, $b = 3$, $c = 5$, &c., as explained on p. 11 of the book); thus, answering to 25 we have *cc*, to 27 *bbb*, to 225 *bb*, *cc*, &c.

Krüger, 1746. At the end of the 'Algebra' is a list of primes to 100,999, arranged consecutively in pages of six columns, and occupying 47 pp. The titlepage runs 'Primzahlen von 1 bis 1000000'; but the limit is as above stated; and there is no possibility that the copy before us is incomplete, as the last page is a short one, and there is no printing on the back.

The primes of each hundred are separated, which for some purposes would be an advantage.

LAMBERT states (Introd. ad 'Supplementa,' &c., 1798) that KRÜGER received this table from Peter Jæger.

Felkel, 1776. Table of all simple factors of numbers to 144,000, the tabular results being obtained from three tables. Thus Table A gives primes to 20,353; these occupy one page, along the top line of which run the Greek letters $\alpha, \beta \ldots$ and down the left-hand column four alphabets consecutively, viz. small italic, small German, capital italic, and capital German (there being 100 lines); and any prime given on this page is henceforth in the book denoted by its coordinates, so to speak: thus 9839 would be printed μp, &c. The principal table occupies 24 pp.; and then Table B occupies one page at the end. Suppose it required to find the factors of 138,593. The middle table is entered at 138 and Table B at 593. In the latter we find as result "g line 20," so that we know that the compartment under g in the 20th line of the block 138, refers to the number in question. In this compartment is printed e, g, βr, which, interpreted by Table A, gives 7, 13, and 1523 as the factors. There are a few details that have been omitted in this description; the last three figures are written in the compartment wherever there is room for them.

On the titlepage is a large engraving of a student (no doubt a portrait of Felkel) turning in contempt from a disordered cabinet of military books to another neatly arranged, containing Euler, Newton, Maclaurin, Bernoulli, Boscovich, &c., and holding in his hand the works of Lambert; with mottoes "Bella odi, Pacem diligo, vera sequor," &c. above. It will be seen that this table is entirely superseded by Chernac and Burckhardt. In the arrangement of the latter the table would only have occupied 16 much smaller pages, and its use would have required no explanation; but on account of the rarity of the work, it has been thought worth while to describe at some length what is certainly the most remarkable-looking table we have seen.

De Morgan states that "Murhard mentions the first part of a table (by A. Felkel) of the factors of all numbers not divisible by 2, 3 or 5 from 1 to *a hundred millions*, Vienna (1776)." On referring to Murhard we find such is the case, "100,000,000" being an obvious misprint for "10,000,000;" we have seen Murhard's error reproduced by other writers.

Of Felkel's table Gauss (in the letter prefixed to DASE's Seventh Million) says: "Felkel hatte die Tafel im Manuscripte bis 2 Millionen fertig und der Druck war bis 408,000 fortgeschritten, dann aber sistirt, und die ganze Auflage wurde vernichtet bis auf wenige Exemplare des bis 336,000 gehenden Theils, wovon die hiesige Bibliothek eines besitzt." The copy of Felkel in the Royal Society's Library, which extends to 144,000, is that which has been described above. Felkel's table is also referred to by HOBERT and IDELER in the introduction to their work (see § 4).

Felkel was editor of the Latin edition (Lisbon, 1798) of LAMBERT's 'Zusätze' (the 'Supplementa' &c., see § 4); and he has there given, in the 'Introductio Interpretis' and at the end, some account of his life and the work he accomplished and hoped to accomplish with regard to the theory of numbers. He commenced the study of mathematics when of a somewhat advanced age; and he speaks in the warmest terms of Lambert, with whom he was in correspondence, and from whom he derived much assistance. This accounts for Lambert being the book open before the student in the engraving described above.

In a note on p. xiv of the Introductio to the 'Supplementa,' he (Felkel)

says : "Non solum inveni formam omnes divisores numerorum excepto maximo, ab 1 usque 1,008,000 in spatio 42 plagularum repræsentandi, verum etiam reipsa opus spatio 16 mensium usque ad 2,016,000 confeci, annoque 1785 .... ad 5,000,000 usque continuavi." (See also p. vii of the 'Introductio Interpretis').

Since writing the above description of Felkel, I have examined (in the Graves Library) a far more complete copy, which contains probably all that Felkel ever printed. There are three parts (bound together). The first is the same as that described above, and extends to 144,000; the second part (with fresh pagination) extends from 144,001 to 336,000 (pp. 2–63); we then have 'Tabula Factorum pars III exhibens factores numerorum ab 336,001 usque 408,000,' occupying pp. 65–87. The table thus gives factors as far as 408,000. The words "336,001 usque 408,000" have clearly originally stood "144,001 usque 366,000;" but the latter numbers have been stamped out and the former printed over them. There is a note in the work in the handwriting of Mr. Graves's librarian, which, referring to Gauss's remark quoted above, proceeds:—"This copy contains 3 parts and gives the factors of all numbers up to 408,000; such a copy is perhaps unique." Gauss stated that all the copies were destroyed except a few, which extended to 336,000; so that there can be no doubt that the Graves copy, extending to 408,000, must be, to say the least, excessively rare.

It should be added that the title and preface to the Graves copy are in Latin, while the Royal Society's copy has them in German (Poggendorff also quotes the title in German with date 1777); the preface is dated April 1, 1777, although the titlepage bears date 1776. In the Graves copy some errata in Part I. are given.

For several reasons Felkel's connexion with numerical tables is a curious one, and the record of his life would be interesting. We have seen (in some work of reference) a number of mechanical contrivances assigned to him as their inventor.

Chernac, 1811. In a thick quarto are given all the simple divisors of numbers from 1 to 1,020,000 (multiples of 2, 3, and 5 being excluded). This book was found by Burckhardt (who subsequently published the same table, the least divisor only being given) to be very accurate; he detected only 38 errors (he has given them in the preface to his first million), of which only 9 are due to the author, the remaining 29 having been caused by the slipping &c. of type in the printing.

Hutton's Phil. and Math. Dict. 1815. In vol. ii. pp. 236–238 (Art. 'Prime Numbers') is a table giving the least divisor of all numbers from 1 to 10,000, multiples of 2 and 5 being omitted.

Burckhardt (First Million), 1817. Least divisors of every number to 1,020,000. The library of the Institute contained a manuscript (calculated by Schenmarck ?) giving the least divisor of numbers to 1,008,000; Burckhardt therefore computed the next 12,000 himself, and compared the manuscript with CHERNAC—a laborious work, as when a wrong divisor was given, Burckhardt had to satisfy himself if the number was really prime, as was the case in 236 instances. For primes less than 400,000 he referred to Vega (see VEGA's 'Tabulæ,' 1797, Vol. II. T. I., and HÜLSSE's VEGA, 1840, T. V.). Only 38 errors were found in CHERNAC. On the last page is a small table containing the number of figures in the periods of the reciprocals of 794 primes below 9901 (779 of which are below 3000). Burckhardt mentions in the preface that he has nearly completed the manuscript of the fourth, fifth, and sixth millions, which will be published, if the sale of the first three millions is

sufficiently favourable to induce the bookseller to undertake them. There are three pages on the use of the tables. This work, though containing the first million, was published after the second and third.

Five errors are pointed out at the beginning of DASE's 'Seventh Million.'

Burckhardt (Second Million), 1814. The arrangement is the same as for the first million; and the table extends from 1,020,000 to 2,028,000. This was the first published of the three millions; and the method of calculation &c. is explained in the introduction, the least factor alone being given. If the others are required, the process is of course to divide the number by this factor and enter the table again with the quotient. To facilitate the division, on the first page (p. viii) a table is given of the first 9 multiples of all primes to 1423.

Burckhardt (Third Million), 1816. The arrangement is the same as in the other millions: the table extends from 2,028,000 to 3,036,000.

Rees's Cyclopædia (vol. xxviii. Art. 'Prime Numbers'), 1819. Attached to the article "Prime Numbers" in Rees's 'Cyclopædia,' is a table of 23 pp., giving a list of primes up to 217,219 arranged in decades—a very convenient table, as there are 910 primes on each page. It is stated (and truly) that the primes are given to twice the extent that they are to be found in any previous English work. In the course of the article the author says, "And a work lately published in Holland, not only contains the prime numbers up to 1,000,000, but also the factors of all composite numbers to the same extent—a performance which, it must be allowed, displays the industry of its author to much more advantage than either his genius or judgement." This can only refer to CHERNAC's table, which was published at Deventer (Daventria) in 1811; and it is a matter of regret that an English writer on mathematics should have thought only deserving of a sneer a work the performance and extension of which had been consistently urged by Euler and Lambert and afterwards by Gauss. One would expect the article of such a writer on the theory of numbers to be very poor; and such is the case. He has not thought it worth while to state where the table he gives has been copied from; it is no doubt taken from VEGA ('Tabulæ'), 1797, Vol. II. T. I.

Dase (Seventh Million), 1862. The least divisor of all numbers from 6,000,001 to 7,002,000 (multiples of 2, 3 and 5 excluded), and therefore also a table of primes between these limits.

The arrangement is as in BURCKHARDT, there being 9000 numbers to the page.

This work was undertaken by Dase at the suggestion of Gauss; and the letter of the latter is printed in the preface. In it Gauss adverts to, and expresses his concurrence in, Felkel's desire that the factorial tables should be extended to ten millions; he states that a manuscript containing the fourth, fifth, and sixth millions (viz. 3,000,000 to 6,000,000) was some years before presented by Crelle to the Berlin Academy, and he expresses a hope that it will soon be published; he therefore suggests that Dase should complete the portion from 6,000,000 to 10,000,000. Dase accordingly undertook the work, and at the time of his death in 1862 had finished the seventh million entirely and the eighth million nearly; while many factors for the ninth and tenth millions had been determined. The seventh million (as also the two following) were published after Dase's death by a committee of his fellow-townsmen as a memorial of his talent for calculation.

Dase (Eighth Million), 1863. The arrangement is the same as in the seventh million; and the table extends from 7,002,001 to 8,010,000; the paging runs from 113 to 224.

There is a short preface of 2 pp. by Dr. Rosenberg, who edited the work, which was left nearly complete by Dase.

Dase and **Rosenberg** (Ninth Million), 1865. The arrangement is the same as in the previous two millions; and the table extends from 8,010,000 to 9,000,000. The work left incomplete by Dase at his death was finished by Dr. Rosenberg; the paging runs from 225–334.

It is stated in the preface that the tenth million (the last which the tables were intended to include) was nearly completed; but we believe it has not yet appeared.

It will have been seen from the above accounts that Chernac's, Burckhardt's, and Dase's tables together contain all the published results with regard to factors of numbers; and by means of them we can find all the simple divisors of numbers between one million and three millions and between six millions and nine millions easily, and between unity and one million at sight. There is, however, the gap from three millions to six millions; and it is very much to be regretted that this is not filled up. Gauss states a table of divisors from three millions to six millions exists in manuscript at Berlin; and Burckhardt also formed a similar table; so that this portion has apparently been twice calculated (by Crelle? and Burckhardt).

Gauss's letter is dated 1850; and it is a calamity that the anticipations contained in it have not been realized, as a manuscript unpublished does more harm than if it were non-existent, by checking others from attempting the task. The completion of Gauss's scheme (viz. the publication of tables to ten millions) is very desirable, as these tables may be regarded as data in regard to investigations in the theory of numbers (see references to memoirs of Euler and Gauss in Chernac, and Gauss's letter). The tenth million also seems to be still unpublished, though seven years ago we had Dr. Rosenberg's assurance that it was nearly completed. If the whole ten millions were published, we should much like to see a list of all the primes up to this point published separately.

Oakes, 1865 (Machine table). The object is to find the prime or least factors of numbers less than 100,000; and for this purpose there are three tables, A (1 page large 8vo), B (4 pp. folio), and C (1 page obl. folio), and nine perforated cards, the one to be employed depending on the group of 10,000 that contains the argument. The mode of entry is somewhat complicated; and the table can only be regarded as a matter of curiosity; for in the method of arrangement of Burckhardt or Dase the least factors of all numbers under 100,000 only occupy a little over 11 pp. or six leaves of small folio or large 8vo size—while the present apparatus consists of six leaves of large and different sizes, and nine cards, besides requiring an involved course of procedure. Col. Oakes does not explain the principle on which his method depends.

The following is a list of tables contained in works that are described in § 4.

Tables of Divisors.—Dodson, 1747, T. XVII. (to 10,000); Maseres, 1795 (to 100,000); Vega, 1797, Vol. II. T. I. (to 102,000); Lambert, 1798, T. I. (to 102,000); Barlow, 1814, T. I. (to 10,000); Hantschl, 1827, T. VII. (to 18,277): *Salomon, 1827, T. II. (to 102,011); Hülsse's Vega, 1840, T. V.; Köhler, 1848, T. VIII. (to 21,524); Hoüel, 1858, T. VII. (to 10,841); Rankine, 1866 (to 256). See also Gruson, 1798, § 3, art. 1.

List of Prime Numbers.—Dodson, 1747, T. XVIII. (10,000 to 15,000); Vega, 1797, Vol. II. T. I. (102,000 to 400,000); Lambert, 1798, T. II.

(multiples of primes); T. VI. (to 102,000); Barlow, 1814, T. V. (to 100,103); Hülsse's Vega, 1840, T. V. (102,000 to 400,313); Minsinger, 1845 [T. II.] (to 1000); Byrne, 1849 [T. I.] (to 5000); Wackerbarth, 1867 (to 1063); Parkhurst, 1871, T. XXIII. (to 12,239).

Art. 9. *Sexagesimal and Sexcentenary Tables.*

Originally all calculations were sexagesimal; and the relics of the system still exist in the division of the degree into 60 minutes, and the minute into 60 seconds. To facilitate interpolation, therefore, in trigonometrical and other tables, several large sexagesimal tables have been constructed, which are described or referred to below. They are, we believe, scarcely used at all now, for several reasons—first, on account of the somewhat cumbrous size of the complete tables, and secondly because for most purposes logistic logarithms (see § 3, art. 18) are found more expeditious and convenient. A third reason is that both Bernoulli's and Taylor's tables were published by the Commissioners of Longitude, and, like the other publications of the Board, were advertised so little that their existence never became generally known.

Bernoulli, 1779. A sexcentenary table to 600 seconds, to every second, giving at once the fourth term of any proportion of which the first term is 600″ and each of the other two are less than 600″. The table is, of course, of double entry; it may perhaps be best described as giving the value of $\frac{xy}{600''}$ correct to tenths of a second, x and y each containing numbers of seconds less than 600″, x being expressed in seconds alone, and y in minutes and seconds (though the latter can be turned into seconds at sight, as the number of seconds in the necessary integer number of minutes is given at the top of each page). The x's run down the left-hand column, and the y's along the top line; and the arrangement is thus:—The portion of x from 1″ to 60″ and the whole range of y is given; this occupies 30 pp.; then the portion for x from 60″ to 120″, and for y from 60″ to 600″; and so on. The chief use of the table consists in the fact that in astronomical tables the differences are usually given for every 10′, so that the interpolation gives rise to a proportion of the kind described above: in some cases the use of the table would be preferable to that of logistic logarithms.

Taylor, 1780 [T. I.] (pp. 240). The table exhibits at sight the fourth term of any proportion where the first term is 60 minutes, the second any number of minutes less than 60, and the third any number of minutes and seconds under 60 minutes. If the second term consists of minutes and seconds, the table must be entered twice (once for the minutes and once for the seconds). The table can of course also be put to other uses.

There is also added a table of the equation of second difference, giving the correction to be applied on this account in certain cases.

[T. II.] (pp. 250, 251). Giving the thirds answering to the decimals in every column of [T. I.] where the result is expressed in minutes, seconds, and decimals of a second.

[T. III.] (pp. 263–312). A millesimal table of proportional parts adapted to sexagesimal proportions, giving the result of any proportion in which the first term is 60 minutes, the second term any number under 60 minutes, and the third term any absolute number under 1000. It is in fact the same as the sexagesimal table [T. I.], only that the third term is expressed in seconds, and is given only to 1000 (16′ 40″), and the result is also expressed in seconds (in [T. I.] the third terms are given both in minutes and seconds) and

in seconds wholly, so that the expression of the result in seconds wholly is the chief characteristic of [T. III.].

This table is followed by 3 pp. to convert sexagesimals into decimals and *vice versâ,* and numbers into sexagesimals and *vice versâ.* The other tables are weights and measures &c. There are numerous examples given in the introduction.

[T. IV.]. Another table occupying one page (p. 252) should be noticed; it gives squares, cubes, fourth, fifth, and sixth powers of any number of minutes up to 60′: thus the square of 3′ is 9″; the cube, 27‴; the fourth power 1‴ 21^{iv}; the fifth 4^{iv} 3^{v}, &c. The words *sursolid* and *square cube* are used for the fifth and sixth powers.

On the present work see also BEVERLEY (1833?) (§ 4).

It was the author of this table (Taylor) who afterwards calculated the logarithmic trigonometrical canon to every second.

The following are references to works in § 4:—

Sexagesimal tables:—LYNN, 1827, T. *Z*; BAGAY, 1829, T. XXIV. (logarithms with sexagesimal arguments); BEVERLEY (1833?), T. VI. (pp. 232 &c.) and T. XV.; SHORTREDE (Com. log. Tab.), 1844; GORDON, 1849, T. XVII. (half sines, &c., expressed sexagesimally).

Tables for the conversion of sexagesimals into decimals, and vice versâ:— DOUGLAS, 1809, T. III., Supplement; DUCOM, 1820, T. XX.; HÜLSSE'S VEGA, 1840, T. IV.

Art. 10. *Tables of natural Trigonometrical Functions.*

A history of trigonometrical tables by Hutton is prefixed to all the editions of his 'Tables of Logarithms' published during his lifetime*; and, in his Article on Tables in the 'English Cyclopædia,' De Morgan has given what is by far the most complete and accurate account of printed tables of this kind that has been published. Information about the earlier tables is also to be found in Montucla and Delambre (see references in De Morgan). For many years, when Mathematics had not passed beyond Trigonometry, the method of construction and calculation of the 'Canon Trigonometricus' formed one of the chief objects of the science, and the works on the subject were comparatively numerous, though now, of course, of purely historic interest only. Prior to the introduction of sines from the Arabians by Albategnius, trigonometrical calculations were always made by chords. The unit-arc was the arc whose chord was equal to the radius (viz. 60°); and both arc and radius were divided into 60 equal parts, and these subdivided again into 60 parts, and so on. (It thus appears that it was not the right angle that was divided into 90, 60 and 60 parts, &c., but that the unit-angle was 60°, so that the division was strictly sexagesimal throughout. It is curious that in some modern tables (see BEVERLEY, T. VI. and XV. &c.) the original arrangement has been restored, for convenience of interpolating by TAYLOR's sexagesimal table). Thus in the earliest existing table, viz. the table of chords in the Syntaxis of Ptolemy (died A.D. 178), the chord of 90° is 84° 51′ 10″. Purbach (born 1423) and Regiomontanus (born 1436) calculated sines, the former to radius 600,000 and the latter to the same radius and also to radius 1,000,000; but it is not certain whether they were printed. The first known printed table, according to De Morgan, is a table of sines to minutes, without date, but previous to 1500. Peter Apian first published a table with the radius divided decimally (1533). Tangents were first pub-

* It also forms Tract XIX. vol. i. pp. 278–306 of his 'Mathematical Tracts,' 1812.

lished by Regiomontanus (1504); and the first complete canon giving all the six ratios of the sides of a right-angled triangle is due to Rheticus (1551), who also introduced the semiquadrantal arrangement. Rheticus's canon was to every ten minutes to 7 places; and Vieta first extended it *to every minute* (1579). The first complete canon published in England was by Blundevile (1594), although a table of sines had appeared four years earlier.

It may be added that Regiomontanus (1504) called his table of tangents (or rather cotangents) *Tabula fœcunda*, on account of its great use; and till the introduction of the word *tangent* by FINCK (1583), a table of tangents was called a *Tabula fœcunda* or *Canon fœcundus*; FINCK also introduced the term *secant*, the table of secants having previously been called *Tabula benefica* by Maurolycus (1558), and *Tabula fœcundissima* by Vieta.

The above historical sketch has been compiled from Hutton and De Morgan; so that most of the statements contained in it are not derived from our own inspection of the works mentioned. It is only intended to give an idea of the history of the natural canon; and from the experience we have had of the value of second-hand information in mathematical bibliography, we should not recommend great reliance to be placed on any one of the facts. A good deal of information about Rheticus, Vieta, &c. is given by De Morgan, whom we have scarcely ever found inaccurate, even in trifling details, when describing works he has examined himself. We have seen several of the works noted, but not sufficient to make any corrections of importance to the current histories.

The next author of importance to RHETICUS was PITISCUS (1613), whose important canon, which still remains unsuperseded, is described below. The invention of logarithms in the following year changed all the methods of calculation; and it is worthy of note that NAPIER's original table of 1614 (see § 3, art. 17) was a logarithmic canon of sines and not a table of the logarithms of numbers. Almost at once the logarithmic superseded the natural canon; and since PITISCUS's time no really extensive table of pure trigonometrical functions has appeared. Natural canons are now most common in Nautical collections, where the tabular results are generally given to 5 or 6 places only.

Traverse tables (multiples of sines and cosines) have not been included (see § 2, art. 12). MASSALOUP (described below), however, is really a table of this kind, although constructed for a different purpose.

Finck [1583]. Canon of sines, tangents, and secants in separate tables, quadrantally arranged, for every minute of the quadrant, to 7 decimal places. The sines occupy pp. 138–173, the tangents pp. 176–221, and the secants pp. 224–269. De Morgan says that Finck calculated his own secants. There is no date on the titlepage; but the preface and the colophon are both dated 1583. The name tangent is introduced by Finck on p. 73, and that of secant on p. 76. These names were speedily adopted: thus Clavius, at the end of his edition of 'Theodosius' (Rome, 1586), reprints Finck's tables, and uses his terms both in the headings of the tables and in the trigonometry. He does not mention either Finck or Rheticus by name, but speaks of them as *recentiores* (p. 188). Pitiscus, in his trigonometry appended to Abraham Shultet's 'Sphæricorum' (Heidelberg, 1595), uses the names tangent and secant, and refers to Finck or Rheticus for the requisite canons; and in his larger trigonometry (Augsburg, 1600) he reprints Finck's tables to five decimals, placing the sines, tangents, and secants together in one table. Blundevile, in his 'Exercises' (London, 1594), reprinted the tables from Clavius. All these works are before us; but a more detailed account would be of only historical or bibliographical interest.

Rheticus, 1596 ('Opus Palatinum'). Complete ten-decimal trigonometrical canon for every ten seconds of the quadrant, semiquadrantally arranged, with differences for all the tabular results throughout. Sines, cosines, and secants are given on the versos of the pages in columns headed respectively *Perpendiculum, Basis, Hypotenusa*; and on the rectos appear tangents, cosecants, and cotangents, in columns headed respectively *Perpendiculum, Hypotenusa, Basis**. This is the celebrated canon of George Joachim Rheticus, the greatest of the table-computers, to whom also is due the canon of sines described below under PITISCUS, 1613. At the time of his death (1576) Rheticus left the canon all but complete; and the trigonometry was finished and the whole edited by Valentine Otho under the title 'Opus Palatinum,' so-called in honour of the Elector Palatine Frederick IV., who bore the expense of publication. The edition before us is in two volumes, the second containing the ten-decimal canon and occupying 540 pp. (2–541) folio; then follow 13 pp. of errata numbered 142–153 and 554. At the end of the first volume is a canon of cosecants and cotangents (in columns headed *Hypotenusa* and *Basis* respectively) to 7 places for every 10 seconds, in a semiquadrantal arrangement. It occupies 180 pp. (separate pagination, 2–181); and there seems no reason why it should have been printed at all, as the great ten-decimal canon completely supersedes it. Besides, it is exceedingly incorrect, as comparison with the latter shows at once. On this point De Morgan says that its insertion "was merely the editor's want of judgment; it is clearly nothing but a previous attempt made before the larger plan was resolved on;" while Hutton writes, "But I cannot discover the reason for adding this less table, even if it were correct, which is far from being the case, the numbers being uniformly erroneous and different from the former through the greatest part of the table." Mention of it is introduced by Hutton with the words, "After the large canon is printed another smaller table," &c., while in the copy before us it ends the first volume, the second containing the great canon. It is also to be inferred from De Morgan's account that the whole work generally is bound in one (very thick) volume. The tangents and secants in the early part of the great canon were found to be inaccurate; and the emendation of them was intrusted to Pitiscus, who "corrected the first eighty-six pages, in which the tangents and secants were sensibly erroneous" (De Morgan); and copies of this corrected portion alone were issued separately in 1607, as well as of the whole table with the corrections. We have not seen one of these corrected copies; but *vide* De Morgan's full account, 'English Cyclopædia,' Article "Tables," and 'Notices of the Roy. Astron. Soc.,' t. vi. p. 213, and 'Phil. Mag.' June, 1845. The pagination of the other parts of the work is 'De Triangulis globi cum angulo recto,' pp. 3–140; 'De Fabrica Canonis,' pp. 3–85; 'De Triquetris rectarum linearum in planitie,' pp. 86–104; 'De Triangulis globi sine angulo recto,' pp. 1–341; 'Meteoroscopium,' pp. 3–121 (the first three by Rheticus and the rest by Otho).

In 1551 Rheticus had published a ten-minute seven-place canon in his 'Canon Doctrinæ Triangulorum,' Leipzig, with which the present work must not be confounded. And in 1579 Vieta published his 'Canon Mathematicus, seu ad triangula cum Adpendicibus,' for every minute of the quadrant. This

* The explanation of these terms is evident. The sines and cosines are perpendiculars and bases to a hypotenuse 10,000,000,000; the secants and tangents are hypotenuses and perpendiculars to a base 10,000,000,000, and the cosecants and cotangents are hypotenuses and bases to a perpendicular 10,000,000,000. The object Rheticus had in view was to calculate the ratios of each pair of the sides of a right-angled triangle.

and several other works that we have examined will be noticed at length in a future Report.

On Rheticus's other works see PITISCUS, 1613, below.

Gernerth has given a list of 598 errors that he found in the first seven or eight figures of the ten-decimal canon in the 'Zeitschrift f. d. österr. Gymn.' VI. Heft, S. 407 (also published separately). He also gives an account of the contents of the 'Opus Palatinum,' from which it appears that in his copy the different parts of it were bound up in a different order from that in which they appear in the copy we have examined (which seems to be anomalous in this respect); and he omits the 121 pp. of the 'Meteoroscopium.' The great inaccuracy of the small canon is also noticed by him; and it is on this account that he gives no errata list for it.

Pitiscus, 1613 [T. I.] (pp. 2–271, calculated by Rheticus). Natural sines for every ten seconds throughout the quadrant, to 15 places, semiquadrantally arranged, with first, second, and third differences. (On p. 13, *Perpendiculum* and *Basis* are printed instead of *Sinus* and *Sinus complementi*).

[T. II.] (pp. 2–61, calculated by Rheticus). Natural sines for every second from 0° to 1°, and from 89° to 90°, to 15 places, with first and second differences.

[T. III. and IV.] (pp. 3–15). The lengths of the chords of a few angles, to 25 places, with verifications &c., followed by natural sines and cosines for the tenth, twentieth, and fiftieth second in every minute to 35′, to 22 places, with first, second, third, fourth, and sometimes fifth differences.

The numbering of the pages thus recommences in each table (except. T. IV.); and each has a separate titlepage. On the first two the date is printed cIↃ . IↃ . XIII. instead of cIↃ . IↃc . XIII.

The rescue of the MS. of this work from destruction by Pitiscus (as told by himself in the preface) forms a striking episode in the history of mathematical tables. The alterations and emendations in the earlier part of the corrected edition of the 'Opus Palatinum' were made by Pitiscus; and he remarked that a table of sines to more places than ten was requisite to enable the corrections to be conveniently made. He had his suspicions that Rheticus had himself calculated a ten-second canon of sines to fifteen decimal places; and on application to Valentine Otho, the original editor of the 'Opus Palatinum,' the latter, who was then an old man, acknowledged that such was the case, but could not remember where the MS. was ("ob memoriæ senilis debilitatem"). He thought that perhaps he had left it at Wittemberg; and accordingly Pitiscus sent a messenger there to search for it; but after considerable expense had been incurred he returned without it. After the death of Otho, when the MSS. of Rheticus, which had been in his possession, passed into the hands of James Christmann, the latter discovered the canon among them, when it had been given up for lost. As soon as Pitiscus knew this he examined the MSS. page by page, although they were in a very bad condition (situ et squalore obsitas ac pæne fœtentes), and to his great satisfaction found:—(1) the ten-second canon of sines to 15 places, with first, second, and third differences (printed in the work under notice); (2) sines for every second of the first and last degrees of the quadrant, also to 15 places, with first and second differences; (3) the commencement of a canon of tangents and secants, to the same number of decimal places, for every ten seconds, with first and second differences; (4) a complete minute-canon of sines, tangents, and secants, also to 15 decimal places. From this account, taken in connexion with the 'Opus Palatinum' and the contents of the present work, one is able to form some idea of the enormous computations undertaken by Rheticus;

his tables not only to this day remain unsuperseded and the ultimate authorities, but also formed the data whereby Vlacq calculated his logarithmic canon. Pitiscus says that for twelve years Rheticus constantly had some computers at work (duodecim totos annos semper aliquot Logistas aluit); and how much labour and expense on his part would have been wasted but for the zeal of Pitiscus is painful to contemplate; as it was, it is matter of regret that Rheticus did not live to see the publication of either of his canons, the first of which appeared twenty years, and the other thirty-seven years after his death. It was Pitiscus's intention to add Rheticus's minute-canon of tangents and secants; but they laboured under the same defect as those in the (uncorrected) 'Opus Palatinum,' and on this account he was dissuaded from so doing by Adrianus Romanus. The matter spoken of above as [T. III. and IV.] was due to Pitiscus himself, and was introduced at the advice of the same mathematician.

The enormous work undertaken by Rheticus needs no eulogy; and the earnestness and love of accuracy displayed by Pitiscus, not only rendered apparent by his acts but also evident in the prefaces to his several works, will always render his an honoured name in science.

The present work is exceedingly rare; and the copy we have examined is in the library of the Greenwich Observatory. It, the 'Opus Palatinum,' and VLACQ's 'Arithmetica Logarithmica,' 1628, and 'Trigonometria Artificialis,' 1633, may be said to be the four fundamental tables of the mathematical sciences.

Gernerth (in the work cited under RHETICUS, 1596, *suprà*) has given a list of 88 errors that he detected in the first 7 or 8 places of the canon of sines; he detected altogether 110; but 22 he states were given by Vega in his 'Logarithmisch-trigonometrische .... Tafeln und Formeln,' Vienna, 1783: this was Vega's first publication of tables; and we have not seen the work.

Grienberger, 1630. Sines, tangents, and secants, to 5 places, for every minute from 0° to 45° (with foot entries also; but the table is only half a complete canon, as *e.g.* sin 50° could not be taken out from it). There are five more figures added to the sines, but separated from them by a point (this is not a true decimal point, as is evident from the rest of the work, where no trace of decimals occurs), the object the author had in view in adding them being that when the sines had to be multiplied by large numbers, the results might still be correct to the last unit (radius 100,000). Grienberger stated that more than 35 years before (about 1595) he had calculated a canon of sines to 16 places, and made considerable progress with the secants when the 'Opus Palatinum' appeared and caused him to lay aside his work. This he regretted exceedingly at the time of writing the present work, as he was not able to add the five extra figures to the tangents and secants, which he had transferred from his MS. in the case of the sines. The 'Opus Palatinum' contained enough figures; but some of them were doubtful, and he wished no doubt to attach to any part of his table. The book is a duodecimo volume, and would scarcely have been noticed here, but from the fact of part of it having been the result of an original calculation. Napier's bones are mentioned, but not logarithms. The preface contains Grienberger's 39-figure value of π (see 'Messenger of Mathematics,' July 1873); and it was in connexion therewith that we sought the work out, and learnt with some surprise of Grienberger's incomplete and unpublished calculations. The copy we examined is in the British Museum.

Massaloup, 1847, T. I. The first five hundred multiples of the sines and

cosines of all angles from 1° to 45° at intervals of 10′ to *two* places. The table occupies 442 closely printed pages.

T. II. gives the first 109 multiples of the sine of all angles from 0° to 15° at intervals of 1′ to two places.

The above is the mathematical description of these tables; but in the book, which is intended for surveyors &c., the multiples correspond to different lengths (1.0, 1.1, ... 50.0 Ruthen) of the hypothenuse; and the sine and cosine columns are headed *Höhe* and *Grundlinie*, and are given in Ruthen. As the arguments are at intervals of a Fuss ($=\frac{1}{10}$ of a Ruthe) the table exhibits the results apparently to 3 places. The arrangement in T. I. is different from that in T. II., as while in the former the Ruthen and Füsse run down the column, and the minutes along the top line (so that all the multiples of the same sine or cosine are given consecutively), in T. II. the minutes run down the column, and the Füsse along the top line (so that the same multiples of different angles are given consecutively). In this table also the results are given to 3 places, if the method of statement used in the book be followed. As it has been assumed that a Ruthe = 10 Fuss, while frequently it = 12 Fuss, T. III. is given to convert decimals into duodecimals, or, more strictly, Ruthen Decimalmaass into Werkmaass and Bergmaass.

T. I. and II. are of course simple traverse tables.

Junge, 1864. Natural sines and cosines for every ten seconds of the quadrant to 6 places. The table is one of the clearest we have seen, the figures being distinct, and plenty of space being left between the columns &c., so as to give a light appearance to the page, though its large size is rather a disadvantage. The tabular results were interpolated for by Thomas's calculating machine from the natural sines in Hulsse's tables; and the last figure may be in error by rather more than half a unit. The connexion between the tables and Thomas's machine, referred to in the title and in the preface, merely amounts, we suppose, to this—that while computers in general use log sines, those who possess Thomas's machine will find it easier to dispense with logarithms and use natural sines and ordinary arithmetic.

***Clouth**. Natural sines and cosines (to 6 places) and their first nine multiples (to 4 places) for every *centesimal* minute of the quadrant, arranged semiquadrantally, the sines and their multiples occupying the left-hand pages, and the cosines the right; the arguments are also expressed in sexagesimal minutes and seconds, the intervals being then 32″·4. We have not seen the work itself, but only a prospectus, containing 2 pp. (108 and 109) as specimens. Judging from this, the book would contain 208 pp. In the copy of the prospectus before us, the words "Mayen (chez l'auteur)" are covered by a piece of paper on which is printed "Halle, Louis Nebert, Libraire-Éditeur." There is no date; but we should judge the table to have been only recently published.

We have also seen advertised 'Tafeln zur Berechnung goniometrischer Co-ordinaten,' by F. M. Clouth—no doubt a German edition of the same work.

The following is a classified list of trigonometrical tables described in § 4.

Sines, tangents, secants, and versed sines.—(To 7 places) Hantschl, 1827, T. V.; Willich, 1853, T. *B*; Hutton, 1858, T. IX.

(To 6 places) Galbraith, 1827, T. VI.

Sines, tangents, and secants.—(To 7 places) Sir J. Moore, 1681 [T. III.];

VLACQ, 1681 [T. I.]; OZANAM, 1685; SHERWIN, 1741 [T. IV.]; HENTSCHEN (VLACQ), 1757 [T. I.]; SCHULZE, 1778 [T. V.]; LAMBERT, 1798, T. XXVI.; DOUGLAS, 1809 [T. III.].

(To 6 places) OUGHTRED, 1657 [T. I.] (centesimal division of the degree); URSINUS, 1827 [T. V.]; BEARDMORE, 1862, T. 38.

(To 5 places) HOÜEL, 1858, T. II.; PETERS, 1871 [T. V.].

Sines and tangents (only).—(To 7 places) BATES, 1781 [T. II.]; VEGA, 1797, T. III.; HOBERT and IDELER, 1799 [T. I.] (centesimal) and B (centesimal); (?) *SALOMON, 1827, T. XII.; TURKISH LOGARITHMS [1834]; HULSSE'S VEGA, 1840, T. III.

(To 6 places) TROTTER, 1841 [T. IV.].

(To 5 places) SCHMIDT, 1821 [T. III.]; RANKINE, 1866, T. 6; WACKERBARTH, 1867, T. VIII.

(To less than 5 places) PARKHURST, 1871, T. XXX. and XXXI.

Tangents and secants (only).—DONN, 1789, T. V. (4 places); [SHEEPSHANKS, 1844] [T. IV.] (4 places).

Sines (alone).—(To 15 places) CALLET, 1853 [T. VII.] (centesimal).

(To 7 places) DONN, 1789, T. III; HASSLER, 1830 [T. V.].

(To 6 places) MASKELYNE (Requisite Tables, Appendix), 1802, T. I.; DUCOM, 1820, T. XIX.; KERIGAN, 1821, T. IX.; J. TAYLOR, 1833, T. XX.; NORIE, 1836, T. XXVI.; GRIFFIN, 1843, T. 19; J. TAYLOR, 1843, T. 32; DOMKE, 1852, T. XXXVI.

(To 5 places) LAMBERT, 1798, T. XXV.; MASKELYNE (Requisite Tables), 1802, T. XVII.; BOWDITCH, 1802, T. XIV.; MOORE, 1814, T. XXIV.; WALLACE, 1815 [T. III.]; GREGORY, &c., 1843, T. X.

Multiples of sines.—SCHULZE, 1778 [T. VI.]; LAMBERT, 1798, T. XXV.

Versed sines (alone).—(To 7 places) Sir J. MOORE, 1681 [T. IV.]; [Sir J. MOORE, 1681, *Versed sines*]; DODSON, 1747, T. XXVI.; DOUGLAS, 1809, [T. IV.]; FARLEY, 1856 [T. I.].

(To 6 places) MASKELYNE (Requisite Tables, Appendix), 1802, T. II.; MACKAY, 1810, T. XLI.; LAX, 1821, T. XVII. (and coversed &c. sines); RIDDLE, 1824, T. XXVIII.; NORIE, 1836, T. XXXVI.; RÜMKER, 1844, T. III.; INMAN, 1871 [T. VIII.] and [T. IX.].

Sines &c. expressed in radicals.—LAMBERT, 1798, T. XIX.; URSINUS, 1827 [T. III.]; VEGA, 1797, Appendix.

Miscellaneous. — $\sin^2 \frac{x}{2}$, ANDREW, 1805, T. XIII; $\sin^2 x$ and $\tan^2 x$, PASQUICH, 1817, T. II.; suversed, coversed, sucoversed sines, LAX, 1821, T. XVII.; $\frac{1}{2}\sin x$, STANSBURY, 1822, T. *Y*; sexagesimal cosecants and cotangents, BEVERLEY (1833 ?), T. VI. (pp. 232 &c.); sexagesimal sines, Id. T. XV.; $\sin\frac{x}{2}$, HÜLSSE'S VEGA T. IV. 1840; $\sin^2\frac{x}{2}$, [SHEEPSHANKS, 1844] [T. VI.]; $\frac{1}{2}\sin x$ expressed sexagesimally, GORDON, 1849, T. XVIII.; see also SCHLÖMILCH [1865 ?].

Note.—A list of tables in which both natural and logarithmic functions are given side by side in the same table is added at the end of § 3, art. 15.

Art. 11. *Lengths of Circular Arcs.*

Tables of the lengths (or longitudes) of circular arcs are very frequently given in collections of logarithmic and other tables; but we have seen none of sufficient extent to be published separately. Angles are measured either by degrees, minutes, &c., or by the ratio which the corresponding arc bears

to the unit arc, or arc equal in length to radius. The latter method is usually described in English text-books under the title "Circular Measure;" so that in the descriptions in § 4 we have spoken indifferently of the length of the arc of x°, the longitude of x°, or the circular measure of x°. The tables of circular arcs usually give the circular measure of 1°, 2°,.. up to 90°, 180°, or sometimes 360°, of 1′, 2′,....60′, of 1″, 2″,....60″, and very often of 1‴, 2‴,....60‴ also. By means of such a table any number of degrees, minutes, &c. can be readily expressed in circular measure.

The following is a detailed list of the *lengths of circular arcs* contained in works described in § 4:—

(To 44 places) Hobert and Ideler, 1799, G (centesimal division).

(To 27 places) Académie de Prusse, 1776 [T. II.]; Schulze, 1778 [T. VII.]; Lambert, 1798, T. XXIII.

(To 25 places) Callet, 1853 [T. V.] (sexagesimal and centesimal).

(To 15 places) Hantschl, 1827, T. X.

(To 12 places) Schmidt, 1821 [T. IV.]; Muller, 1844 [T. IV.].

(To 11 places) Vega, 1794, T. II.; Hülsse's Vega, 1840, T. II.; Köhler, 1848 [T. V.].

(To 10 places) Shortrede, 1849, T. III.; Bruhns, 1870.

(To 8 places) Vega, 1797, T. III.; Pearson, 1824 [T. III.].

(To 7 places) Dodson, 1747, T. XXV.; Ursinus, 1827 [T. III.]; Gruson, 1832, T. VI.; Trotter, 1841 [T. VII.]; Shortrede (tables), 1844, T. XXXVIII.; Warnstorff's Schumacher, 1845 [T. II.]; Willich, 1853, T. *D*; Bremiker's Vega, 1857, T. II.; Hutton, 1858, T. XI.; Dupuis, 1868, T. IX.; Peters, 1871 [T. III.]

(To 6 places) Bremiker, 1852, T. II.

(To 5 places) Wackerbarth, 1867, T. IV.

See also Vega, 1800, T. II.; Byrne, 1849 [T. II.]; *Schlömilch [1865?].

Art. 12. *Tables for the expression of hours, minutes, &c. as decimals of a day, and for the conversion of time into space, and vice versâ.*

The largest table we have seen to convert hours, minutes, &c. into decimals of a day is Houël, 1866. Tables of this kind are not numerous.

Three hundred and sixty degrees of space or arc are equivalent to twenty-four hours of time; so that 1^h corresponds to 15°, 1^m to 15′, and 1^s to 15″; 1″ is therefore 4 *thirds* of time $=4^t$; $36' = 2^m\ 24^s$ &c. Small tables to convert space (arc, or longitude) into time are not unfrequently given in collections (generally nautical) of tables. A complete table of the kind gives the numbers of hours and minutes corresponding to 1°, 2°,....360°; and the same figures also denote the number of minutes and seconds, and seconds and thirds (of time) corresponding to 1′, 2′,.... 360′, or 1″, 2″,....360″ respectively. In this Report ^{h}, ^{m}, ^{s}, &c. are used to denote hours, minutes, seconds, and thirds (of time), and °, ′, ″, ‴ for degrees, minutes, &c. of space—a distinction which it is often convenient to adopt.

Littrow, 1837. T. I.–IV. (5 pp.) are small tables for the conversion of arc into time &c. All the other tables, which occupy more than nine tenths of the tract, are astronomical.

Houël, 1866 (Time Tables), T. II. To convert hours, minutes, and seconds into the decimal of a day (pp. 15). Any number of hours, minutes, and seconds (and fractions of a second, as proportional parts are added)

can be readily expressed as a decimal (to seven places) of a day, and *vice versâ* by means of it.

The following are tables described in § 4:—

Tables for the conversion of Time into Space, and vice versâ.—Crosswell, 1791, T. XIII.; Bowditch, 1802, T. XII.; Rios, 1809, T. XVI.; Kerigan, 1821, T. XIII.; Stansbury, 1822, T. I.; Pearson, 1824 [T. I.]; Galbraith, 1827, T. XII. (Introd.); Warnstorff's Schumacher, 1845 [T. I.]; Köhler, 1848 [T. I.]; Gordon, 1849, T. XI.; Domke, 1852, T. XLVII. and XLVIII.; Bremiker, 1852, T. II.; Thomson, 1852, T. I.; Bremiker's Vega, 1857, T. III.; Hoüel, 1858, T. I.; Peters, 1871 [T. II.].

Tables to express Degrees, Minutes, &c. as decimals of a right angle, or Hours, Minutes &c. as decimals of a day, and vice versâ, &c.—Hobert and Ideler, 1799, C. I.–IV., D. I.–III., E. I.–IV., F.; Galbraith, 1827, T. XI. (Introd.); Hantschl, 1827, T. XII.; Beverley (1833 ?), T. VI. (p. 127); Köhler, 1848, T. IX.; Peters, 1871 [T. I.].

Art. 13. *Tables of (Briggian) Logarithms of Numbers.*

The facts relating to the invention of Briggian (or decimal) logarithms are as follows:—In 1614 Napier published his 'Canon Mirificus' (see § 3, art. 17), which contained the first announcement of the invention of logarithms, and also a table of logarithmic sines, calculated so as to be very similar to what are now called *hyperbolic* logarithms. Henry Briggs, then Professor of Geometry at Gresham College, London, and afterwards Savilian Professor of Geometry at Oxford, admired this work so much that he resolved to visit Napier. "Naper, lord of Markinston, hath set my head and hands at work with his new and admirable logarithms. I hope to see him this summer, if it please God; for I never saw a book which pleased me better, and made me more wonder." This he says in a letter to Usher (Usher's 'Letters,' p. 36, according to Ward). Briggs accordingly visited Napier, and stayed with him a whole month (in 1615). He brought with him some calculations he had made, and suggested to Napier the advantages that would result from the choice of 10 as a base, having publicly explained them previously in his lectures at Gresham College, and written to Napier on the subject. Napier said that he had already thought of the change, and pointed out a slight improvement, viz. that the characteristics of numbers greater than unity should be positive, and not negative, as Briggs suggested. Briggs visited Napier again in 1616, and showed him the work he had accomplished, and, as he himself says, would have gladly paid a third visit in 1617, had Napier's life been spared (he died April 4, 1617). The work alluded to is Briggs's 'Logarithmorum Chilias Prima,' which was published (privately, we believe) in 1617, after Napier's death, as in the short preface he states that why his logarithms are different from those introduced by Napier "sperandum, ejus librum posthumum, abunde nobis propediem satisfacturum." The *liber posthumus* was Napier's 'Constructio,' which appeared in 1619, edited by his son (see § 3, art. 17). Briggs continued to labour assiduously, and in 1624 published his 'Arithmetica Logarithmica,' giving the logarithms of the numbers from 1 to 20,000, and from 90,000 to 100,000 (and in some copies to 101,000), to 14 places.

To the above facts we must add that Napier made a remark, both in Wright's translation of the 'Descriptio' (1616) and in the 'Rabdologia' (1617), to the effect that he intended in a second edition to make an alteration equivalent to taking the logarithm of 10 equal to unity.

We have thought it proper to give the circumstances attending the inven-

tion of Briggian logarithms in the above detail, as there seems every probability that the relations of Napier and Briggs may become a subject of controversy among those who have never taken the trouble to examine the original sources of information. Hutton, in his 'History of Logarithms' (prefixed to all the early editions of his logarithmic tables, and also printed in vol. i. pp. 306–340 of his 'Tracts,' 1812), has unfortunately interpreted all Briggs's statements with regard to the invention of decimal logarithms in a manner clearly contrary to their true meaning, and unfair to Napier. In reference to the remark in Briggs's preface to the 'Chilias,' that *it is to be hoped* that the posthumous work will explain why the logarithms are different from Napier's, Hutton proceeds:—"And as Napier, after communication had with Briggs on the subject of altering the scale of logarithms, had given notice, both in Wright's translation and in his own 'Rabdologia,' printed in 1617, of his intention to alter the scale (though it appears very plainly that he never intended to compute any more), without making any mention of the share which Briggs had in the alteration, this gentleman modestly gave the above hint. But not finding any regard paid to it in the said posthumous work, published by Lord Napier's son in 1619, where the alteration is again adverted to, but still without any mention of Briggs, this gentleman thought he could not do less than state the grounds of that alteration himself.

"Thus, upon the whole matter, it seems evident that Briggs, whether he had thought of this improvement in the construction of logarithms, of making 1 the logarithm of the ratio 10 to 1 before Lord Napier or not (which is a secret that could be known only to Napier himself), was the first person who communicated the idea of such an improvement to the world; and that he did this in his lectures to his auditors at Gresham College in the year 1615, very soon after his perusal of Napier's 'Canon Mirificus Logarithmorum' in the year 1614. He also mentioned it to Napier, both by letter in the same year and on his first visit to him in Scotland in the summer of the year 1616, when Napier approved the idea, and said it had already occurred to himself, and that he had determined to adopt it. It would therefore have been more candid in Lord Napier to have told the world, in the second edition of this book, that Mr. Briggs had mentioned this improvement to him, and that he had thereby been confirmed in the resolution he had already taken, before Mr. Briggs's communication with him, to adopt it in that his second edition, as being better fitted to the decimal notation of arithmetic which was in general use. Such a declaration would have been but an act of justice to Mr. Briggs; and the not having made it cannot but incline us to suspect that Lord Napier was desirous that the world should ascribe to him alone the merit of this very useful improvement of the logarithms, as well as that of having originally invented them; though, if the having first communicated an invention to the world be sufficient to entitle a man to the honour of having first invented it, Mr. Briggs had the better title to be called the first inventor of this happy improvement of logarithms."

The above comments of Hutton's are all the more unfortunate because they occur in a history that is generally accurate and truthful. It is needless to say that, the facts being as above narrated, there is not the smallest ground for imputing unfairness to Napier; but Hutton seems to have somehow become possessed of such an idea and read all the facts by the light of it. On the other hand, however, some of the accounts are scarcely fair to Briggs. Mr. Mark Napier, in his 'Memoirs of John Napier,' has successfully refuted Hutton; but he has fallen into the opposite extreme of extravagantly eulogizing Napier at the expense of Briggs, whom he reduces to the level of a mere

computer; and in these terms Mr. Sang has also recently spoken of the latter. Mr. Napier attributes Hutton's assertions to national jealousy (!); and it will be a matter of regret if any other writers should follow his example in attempting to glorify Napier by depreciating Briggs. The words of the latter, in the 1631 translation (and amplification, see below) of his 'Arithmetica' of 1624, are:—"These numbers were first invented by the most excellent Iohn Neper, Baron of Marchiston; and the same were transformed, and the foundation and use of them illustrated with his approbation [ex ejusdem sententia] by Henry Briggs." No doubt the invention of decimal logarithms occurred to both Napier and Briggs independently; but the latter not only first announced the advantage of the change, but actually completed tables of the new logarithms. Thus, as regards the idea of the change, Napier and Briggs divide the honour equally; while, on the principle that "great points belong to those who make great points of them," nearly all belongs to Briggs.

On the subject of Briggs and the invention of logarithms, see the careful and impartial life of Briggs in Ward's 'Lives of the Professors of Gresham College,' London, 1740, pp. 120–129, and also 'Vitæ quorundam eruditissimorum et illustrium virorum' &c., scriptore Thoma Smitho, Londini, 1707 (Vita Henrici Briggii), as well as 'Memoirs of John Napier of Merchiston,' by Mr. Mark Napier, Edinburgh, 1839, and the same author's 'Naperi libri qui supersunt' (see § 3, art. 17). See also Hutton's account (reference given above) and Phil. Mag., October and December (Supplementary No.) 1872, and May 1873. It is proper to add that the date we have given for Briggs's first visit to Napier, viz. 1615, is different from that assumed by other writers, viz. 1616; we have, however, little doubt that the former is correct, as it in all respects agrees with the facts. The reason that Ward, Hutton, &c. assign Briggs's first visit to 1616, and the publication of the 'Chilias' to 1618, is, no doubt, due to the fact that they supposed Napier to have died in 1618; but Mr. Mark Napier has shown that the true date is 1617; and this brings all the facts into agreement (see Phil. Mag. December 1872, Supp.).

Like Napier, Briggs was not very particular about the spelling of his name. In Wright's translation it appears as Brigs on the titlepage, Brigges on the first page of the preface, and Briggs in the eulogistic verses.

Although we have spoken of logarithms *to the base* 10 &c., we need scarcely observe that, although exponents and even fractional exponents were in a sort of way introduced by Stevinus, neither Napier nor Briggs, nor any one till long after, had any idea of connecting logarithms with exponents.

To return to the original calculation of the logarithms of numbers. Briggs, as has been stated, published the logarithms of the numbers from 1 to 20,000 and from 90,000 to 100,000 to fourteen places, in his 'Arithmetica.' There was thus left a gap from 20,000 to 90,000, which was filled up by Adrian Vlacq (although Briggs had in the mean time nearly completed the necessary calculations; see Phil. Mag. May 1873), who published at Gouda, in 1628, a table containing the logarithms of the numbers from unity to 100,000 to 10 places of decimals. Having calculated 70,000 logarithms and copied only 30,000, Vlacq would have been quite entitled to have called his a new work. He designates it, however, only a second edition of Briggs, the title running, "Arithmetica logarithmica sive logarithmorum chiliades centum, pro numeris naturali serie crescentibus ab Unitate ad 100000....., Editio secunda aucta per Adrianum Vlacq, Goudanum.....Goudæ, excudebat Petrus Rammasenius, 1628." This table of Vlacq's was published, with an English explanation prefixed, in London in 1631, under the title, "Logarithmicall Arithmetike, or Tables of Logarithmes for absolute numbers, from an

unite to 100000.....London, printed by George Miller, 1631" (full titles are given in § 5).

Speaking of Briggs's 'Arithmetica Logarithmica' of 1624, De Morgan, in his article on Tables in the 'English Cyclopædia,' says :—"After his [Briggs's] death, in 1631, a reprint was, it is said, made by one George Miller; the Latin title and explanatory parts were replaced by English ones—'Logarithmicall Arithmetike' &c. We much doubt the reprint of the tables, and think that they were Briggs's own tables, with an English explanation prefixed in place of the Latin one. Wilson (in his 'History of Navigation,' prefixed to the third edition of Robertson) says that some copies of Vlacq, of 1628, were purchased by our booksellers, and published at London with an English explanation premised, dated 1631. Mr. Babbage (to whose large and rare collection of tables we were much indebted in the original article) has one of these copies; and the English explanation and title is the same as that which was in the same year attached to the asserted reprint of Briggs. We have no doubt that Briggs and Vlacq were served exactly in the same manner." On referring to Robertson (fourth edition, p. xvi), there is found to be no further information than that contained in the above extract. That De Morgan's suggestion is quite correct, and that Miller's and Vlacq's tables are both printed from the same types, we have assured ourselves by a most careful comparison, which leaves no doubt whatever that the two works are printed from the same type throughout. We are thus enabled to state that the same errata-list suffices for both; and this is important, as VLACQ (1628, or 1631) is still the most convenient and most used ten-figure table in existence. Briggs's friends were annoyed at Vlacq's publication; but it must be borne in mind that their objections have reference, not so much to the table (which is the only thing of practical importance now) as to the prefixed trigonometry, which Vlacq curtailed in his "second edition." George Miller also published some copies of the original 'Arithmetica' of 1624, with the same titlepage and introduction as were prefixed to the copies of Vlacq of 1628; and this was distinctly wrong, as the titlepage does not in this case describe the contents correctly.

It thus appears that BRIGGS's table was published in 1624, and VLACQ's in 1628—that copies of the tabular portions of both these works were obtained by George Miller, and published by him in 1631, with the same (English) titlepage and introduction, which, though correctly describing the contents of Vlacq, is quite inappropriate for Briggs. This has led to a very great amount of confusion, which has been greatly increased by the fact that on the titlepages Briggs's and Neper's names occur, and that Vlacq only called his work a second edition. It is in consequence exceedingly common to see Vlacq's work assigned to Briggs or Neper; and it is almost invariably ascribed to one or other of the latter in the catalogues of libraries.

VLACQ's 'Arithmetica' of 1628 was also published with the same date, with a French title ("Arithmétique Logarithmétique" &c.) and introduction. Vlacq modestly describes his share of the calculation in the words :—"La description est traduit du Latin en François, la premiere Table augmentée, et la seconde composée par Adriaen Vlacq." Miller's (1631) copies of Vlacq are not so rare as the extract from De Morgan might imply. We have seen five of them, and only three or four of the original (1628) works (including both Latin and French).

In 1631 VLACQ published his 'Trigonometria Artificialis' (§ 4). This work contains, among other tables, the logarithms of the numbers from unity to 20,000, printed also (with the exception of the last sheet, referred to further on) from the same type.

No further calculation of logarithms of numbers took place till the end of the last century, when the great French manuscript tables (the 'TABLES DU CADASTRE'—see description of them below) were computed under the direction of Prony. These, as is well known, have never been published.

In 1794 VEGA published his 'Thesaurus Logarithmorum Completus,' which contains a complete ten-figure table from 1000 to 101,000. It was not, however, the result of a fresh calculation, but was copied from Vlacq, after examination and correction of many errors (see VEGA's 'Thesaurus,' § 4).

In 1871 Mr. SANG published his seven-figure table of logarithms of numbers to 200,000, the second half of which was obtained by a new calculation. It is thus seen that, with the exception of the TABLES DU CADASTRE, and the second half of Mr. SANG's table, every one of the hundreds of the tables that have appeared has been copied from BRIGGS or VLACQ; and considering the enormous number of calculations in which logarithms have been employed, and the vast saving they have effected of labour, it must be admitted that (apart from the fact that the great tables of BRIGGS and VLACQ remain still unsuperseded) great historical interest attaches to the original computation.

VLACQ's ten-figure table contains about 300 errors (leaving out of consideration errors affecting only the last figure by a unit). The greater number of these were found either by Vega, or by Lefort from comparison with the TABLES DU CADASTRE: complete references and a small subsidiary list are given in the 'Monthly Notices of the Royal Astronomical Society' for May and June 1872. While speaking of ten-figure logarithms, we may mention PINETO's table described below; but VLACQ (1628 or 1631) and VEGA (1794) are far preferable: they are unfortunately so rare, however, that not many besides those who have access to a good library can make use of them, and, except to a few, the employment of ten-figure logarithms in their most convenient form is denied: we much prefer VLACQ to VEGA for use, as the arrangement is more convenient.

To return to the history of logarithmic tables to a less number of figures. In 1625 Wingate published at Paris his 'Arithmétique Logarithmétique,' containing seven-figure logarithms to 1000, and logarithmic sines and tangents from GUNTER (see De Morgan; the full title of the Gouda edition of Wingate (1628) is given by Rogg, p. 408), thus introducing Briggian logarithms into France; and in 1626 appeared both HENRION's 'Traicté' (§ 4) at Paris, containing 20,000 logarithms from Briggs and Gunter's logarithmic sines and tangents, and DE DECKER's 'Nieuwe Telkonst' (§ 4) at Gouda, giving also logarithms from Briggs and Gunter; then Vlacq began to calculate logarithms, and brought them in 1628 to the state in which they now are. There is a table of logarithms in NORWOOD's 'Trigonometric' (1631); and in 1633 appeared ROE's table (§ 4), in which the first four figures of the logarithm are printed at the top of the column. This was an advance halfway to the modern arrangement, which was introduced in its present form in JOHN NEWTON's eight-figure table (1658). On FAULHABER, 1631, and OUGHTRED, 1657, see § 4.

Tables of seven- and five-figure logarithms are too numerous to notice here separately. The chief line of descent is BRIGGS, VLACQ, ROE, perhaps NEWTON, the editions of SHERWIN, GARDINER; and then both HUTTON and CALLET bring down the succession to the present day. A very fair account of several logarithmic tables is given by Rogg in section iv. "Elementar-Geometrie" (B) of his 'Handbuch,' who added to the books described in this part of his bibliography a description of the contents. But the reader must be warned against trusting his accounts, except where he is clearly describing

works he has seen. Of seven-figure tables we have found BABBAGE as convenient as any, and it is nearly free from error; CALLET and HUTTON are also much used; SHORTREDE and SANG are both conspicuous for giving the multiples of the differences instead of proportional parts; the latter work also extends to 200,000 instead of 100,000 as usual. Of five-figure tables DE MORGAN'S (Useful-Knowledge Society) tables are considered the best, and are practically free from error. We cannot, however, here particularize the advantages of the different tables, which must be gathered from their full descriptions. Some of them have, of course, been merely included on account of their historical value. We may here mention that the subject of errors in these tables will be considered in a subsequent Report.

Vega (p. iii of the Introduction to the 'Thesaurus,' 1794) says that Vlacq's 'Arithmetica' (1628) and 'Trigonometria' (1633) were printed at Pekin in 1721, under the title "Magnus Canon Logarithmorum, tum pro sinibus ac tangentibus ad singula dena secunda, tum pro numeris absolutis ab unitate ad 100,000. Typis sinensibus in Aula Pekinensi, jussu Imperatoris excusus, 1721" (three volumes folio, on Chinese paper), and that a copy had been offered him for sale two years previously (1792). Montucla ('Histoire,' vol. iii. p. 358) says, the name of the Emperor in question was Kang-hi.

Rogg also (p. 408) confirms Vega, extracting the title from Brunet's 'Manuel du Libraire.'

In the preface to his tables (1849) Mr. Filipowski concludes by a sneering remark on the Chinese, saying that Mr. Babbage proved, "as had long been suspected, from what source those original inventors had derived their logarithms;" and we have noticed this tendency to ridicule the Chinese in this matter as detected plagiarists in others. In point of fact there is no more plagiarism than when Babbage or Callet publishes a table of logarithms without the name of Vlacq on the titlepage. The first publication in China, we infer from Rogg, merely professed to be a reprint of Vlacq; and if logarithms came into general use, it is natural that they would be published, as with us, without the original calculator's name. The fault is with those who form preconceived opinions on subjects they have not investigated.

A Turkish table of logarithms is described in § 4. A small table of logarithms to base 2 is noticed below, under MONTFERRIER, 1840.

We may mention a little book, 'Instruction élémentaire et pratique sur l'usage des Tables de Logarithmes,' by Prony (Paris, 1834, 12mo), which explains the manner of using of tables of logarithms &c., adapted to CALLET.

In many seven-figure tables of logarithms of numbers the values of S and T are given at the top of each page, with V, the variation of each, for the purpose of deducing log sines and tangents. S and T are the values of $\log \dfrac{\sin x}{x}$, and $\log \dfrac{\tan x}{x}$ for the number of seconds denoted by certain numbers (sometimes only the first, sometimes every tenth) in the number-column on each page. Thus, in CALLET, 1853, on the page of which the first number is 67200, $S=\log \dfrac{\sin 6720''}{6720}$ and $T=\log \dfrac{\tan 6720''}{6720}$, while the V's are the variations of each for 10″. To find then, say, log sin 1° 52′ 12″·7, or log sin 6732″·7, we have $S=4{\cdot}6854980$, and log $6732{\cdot}7=3{\cdot}8281893$, whence, by addition, we have $8{\cdot}5136873$; but V for 10″ is $-2{\cdot}29$; whence the variation for 12″·7 is -3, and the log sine required is $8{\cdot}5136870$. Tables of S and T are frequently called, after their inventor, Delambre's tables.

It is only since the completion of this Report, and therefore too late to

make any use of it, that we have received from Professor Bierens de Haan a copy of a very valuable tract, 'Jets over Logarithmentafels,' extracted from the 'Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen, Afdeeling Natuurkunde,' Deel xiv. Amsterdam, 1862, 8vo (pp. 80), which contains by far the most complete list of authors or editors of logarithmic tables of all kinds, with the dates and places of publication (from 1614 to 1862), that we have seen, and must be nearly perfect. Some remarks are made on those of them that de Haan has examined himself; and there is appended a valuable index of reference to papers on logarithms that have appeared in any Journal or Society's Proceedings.

We may also refer to the paper of Gernerth's noticed under Rheticus, 1596 (§ 3, art. 10), which contains a number of last-figure errors in logarithmic and other tables. Gernerth was desirous of ascertaining the care bestowed on the editing of mathematical tables, and considering that it was best measured by the accuracy of the last figure, he confined himself to the examination of this point alone (except in the cases of Rheticus and Pitiscus, where the first seven or eight figures were included), and detected very many errors. He altogether examined tables by eighteen authors; but generally, where the errors were numerous, he has given only five per cent. of those that he found.

Also, as this sheet is passing through the press, we add references to two papers in the 'Monthly Notices of the Royal Astronomical Society' for April and May, 1873, "On the Progress to accuracy of Logarithmic Tables," and "On Logarithmic Tables;" in the former of which the number of Vlacq's original errors that were reproduced in succeeding works is discussed, while the latter contains remarks on logarithmic tables both of numbers and trigonometrical functions. An abstract of the first appears also in the 'Journal of the Institute of Actuaries,' vol. xvii. pp. 352–354.

Briggs, 1617. Logarithms of numbers from unity to 1000 to 14 places of decimals. This was the first table of Briggian logarithms calculated or published. Neither author's name nor date nor place appears on the title-page of the work, which is a mere tract of 16 pp. (at all events in the Brit. Mus. copy); but that it was published by Briggs in 1617 is beyond doubt (see 'Phil. Mag.' *loc. cit.* below).

The preface concludes with the motto "In tenui; sed non tenuis fructusve laborve." On the work see the introductory remarks to this Article, and also 'Phil. Mag.' December (Supplementary No.) 1872. It is stated by Hutton and all the other writers to be an 8-place table; but it really is as described above. One reason for the universal error is that copies are so extremely rare that we have only been able to see one *, viz. that in the British Museum, in the catalogue of which it is entered under Logarithms, and marked as of [1695 ?]. The book is not in the printed Bodleian Catalogue. It is peculiarly interesting as being the first publication of decimal logarithms. Nearly all the descriptions and bibliographies will be found very erroneous, several confounding it with Wright's translation of Napier's 'Canon' (see § 3, art. 17).

Briggs, 1624. Logarithms of numbers from 1 to 20,000, and from 90,000 to 100,000, to 14 places, with interscript differences. The characteristics to the logarithms are given; and this has led to the table being sometimes erroneously described as being to 15 places. The table occupies 300 pages.

* We think we remember to have met with another among the Birch MSS. in the British Museum.

Several lists of errata in this work have been given—viz. by VLACQ in his 'Arithmetica,' by SHERWIN in his tables, by VEGA (folio, 1794), by LEFORT ('Annales de l'Observatoire de Paris'). The introduction occupies 88 pages, and is in Latin.

In some copies there is an additional chiliad added, so that the range of the second portion of the table is from 90,000 to 101,000; and there is a table of square roots of numbers up to 200, to 10 places, occupying the last two pages: these copies are very rare. There is one in the Library of Trinity College, Cambridge, with the following note in it by Dr. Brinkley:—

"This is a very scarce copy, having an addition very rarely to be met with. *Vide* Hutton's preface to his 'Logarithms,' p. 33, who could never find a copy with the addition." Mr. Merrifield has also one of these copies.

On this work see the introductory remarks to this Article.

Tables du Cadastre. On the proposition of Carnot, Prieur, and Brunet, the French Government decided in 1784 that new tables of sines, tangents, &c., and their logarithms, should be calculated in relation to the centesimal division of the quadrant. Prony was charged with the direction of the work, and was expressly required "non seulement à composer des Tables qui ne laissassent rien a désirer quant à l'exactitude, mais à en faire le monument de calcul le plus vaste et le plus imposant qui eût jamais été exécuté ou même conçu,"—an order faithfully carried out. Prony divided the calculators &c. into three sections: the first consisted of five or six mathematicians (including Legendre), who were engaged in the purely analytical work, or the calculation of the fundamental numbers; the second section consisted of seven or eight calculators possessing some mathematical knowledge; and the third comprised the ordinary computers, 70 or 80 in number. The work, which was done wholly in duplicate, and independently by the two divisions of computers, occupied two years.

As a consequence of the double calculation, there are two manuscripts in existence, one of which has been long deposited in the Archives of the Observatory; the other, though supposed to be in the Archives of the Bureau des Longitudes, was in reality in the possession of Prony's heirs, by whom it was presented to the Library of the Institute in 1858.

Each of the two manuscripts consists essentially of 17 large folio volumes, the contents being as follows:—

Logarithms of numbers to 200,000	8 vols.
Natural sines	1 vol.
Logarithms of the ratios of arcs to sines from $0^q\cdot00000$ to $0^q\cdot05000$, and log sines throughout the quadrant ..	4 vols.
Logarithms of the ratios of arcs to tangents from $0^q\cdot00000$ to $0^q\cdot05000$, and log tangents throughout the quadrant	4 ,,

It would take too much space to state the intervals &c. in detail. Speaking generally, the trigonometrical functions are given for every hundred-thousandth of the quadrant (10″ centesimal or 3″·24 sexagesimal). The tables were all calculated to 14 places, with the intention of publishing only 12; but M. Lefort, who has recently examined them, states that the twelfth figure may be in error by as much as 0·8 of a unit in this place, though a little additional care would have rendered it more accurate. The Institute copy has also a table of the first 500 multiples of certain sines and cosines; and the Observatory copies have an introduction containing, among several other subsidiary tables, the first

26 powers of $\frac{\pi}{2}$ to 28 figures. It may be mentioned that the logarithms of 10,000 primes were calculated to 19 places, and the natural sines for every minute (centesimal) to 22 places. This account of the 'Tables du Cadastre' has been abridged from a memoir by M. Lefort, in t. iv. (pp. [123]–[150]) of the 'Annales de l'Observatoire de Paris' (1858), where an explanation of the methods of calculation, with the formulæ &c., is given. The printing of the table of natural sines was once begun. M. Lefort says that he has seen six copies, all incomplete, although including the last page. De Morgan also mentions that he had seen some of the proofs. Babbage compared his table with the 'Tables du Cadastre;' and M. Lefort has given, by means of them, most important lists of errors in VLACQ and BRIGGS; but these are almost the only uses that have been made of tables the calculation of which required so great an expenditure of time and money. "In 1820," says De Morgan, "a distinguished member of the Board of Longitude, London, was instructed by our Government to propose to the Board of Longitude of Paris to print an abridgment of these tables, at the joint expense of the two countries. £5000 was named as the sum which our Government was willing to advance for this purpose; but the proposal was declined" (Penny Cyclopædia, Article "Prony"). The value of the logarithms of numbers is now materially lessened by Mr. Sang's seven-figure table from 20,000 to 200,000 (see SANG, 1871, in this Article).

Rogg (p. 241) gives the title "Notice sur les grandes tables logarithm. et trigonom. calculées au Bureau du Cadastre," Paris, an IX. (=1801), and on the subject gives a reference to Benzenberg's 'Angewandte Geom.' iii. p. 557.

Hill, 1799. Five-figure logarithms from 1 to 100 and from 1000 to 10,000, printed at full length, and with characteristics—no differences (pp. 23–38). The author was an accountant; and the table was intended for commercial purposes, its use in which is explained in the book.

Reishammer, 1800. These are commercial logarithms, intended for merchants &c. When the number is less than unity, the logarithm of its reciprocal (which the author calls the *logarithme négatif*) is tabulated; if greater than unity, its own logarithm (*logarithme positif*). The first table (which only occupies 2 pages) gives the *logarithmes négatifs* of the fractions from $\frac{1}{400}$ to 1, at intervals of $\frac{1}{400}$ to 5 places (the characteristics are given, and not separated from the other figures). This is followed by the principal table, which occupies 117 pages. On the first page are given the *logarithmes négatifs* of 128 fractions, viz. of all proper fractions whose denominators are 60, 48, 40, or 32, arranged in order thus:—$\frac{1}{60}$, $\frac{1}{48}$, $\frac{1}{40}$, $\frac{1}{32}$, $\frac{1}{30}$, ... $\frac{47}{48}$, $\frac{59}{60}$, $\frac{60}{60}$. The rest of the logarithms are *positifs*; and the arguments proceed from 1 to 111, with the 128 fractions just described intermediate to each integer. Thus we have $1\frac{1}{60}$, $1\frac{1}{48}$, &c., $2\frac{1}{60}$, $2\frac{1}{48}$, &c., as arguments. The arguments then proceed from 111 to 207 at intervals of $\frac{1}{32}$, from 207 to 327 at intervals of $\frac{1}{16}$, thence to 807 at intervals of $\frac{1}{8}$, and from 808 to 10,400 at intervals of unity,—all to 5 places. The characteristics are given throughout. A page of proportional parts is added.

There are besides several small tables, to facilitate the calculations, only one of which requires notice. It gives on a folding sheet the 128 fractions previously described, expressed as fractions with denominators 100 and 10, and also (when the numerator is integral) expressed as fractions with denominators 60, 48, 40, 32, 30, 24, 20, 16, 15, 12, 8, 6, 5, 4, 3, 2. Thus $\frac{5}{48}$ $=10\frac{5}{12}\div100$, and$=1\frac{1}{24}\div10$; as it cannot be expressed in lower terms

(or higher terms with any of the above denominators), it only appears as 5 in the 48 column.

In reference to a work by Girtanner (1794) which we have not seen, but which appears to be very similar to the present, De Morgan justly remarks, "But it will not do: Mohammed must go to the mountain. When coinage, weights, and measures are decimalized, the use of logarithms will follow as a matter of course. It is useless trying to bring logarithms to ordinary fractions."

Rees's Cyclopædia (Art. "Logarithms," vol. xxi.), 1819. Seven-figure logarithms of numbers from 1000 to 10,000, with differences; arranged in groups of five.

Schrön, 1838. Three-figure logarithms to 1400, and five-figure logarithms to 14,000, with corresponding degrees, minutes, &c., and proportional parts. Of the 20 pages 4 are occupied with explanations &c. The arrangement is as in seven-figure tables.

Steinberger, 1840. The titlepage is misleading; the logarithms do not extend from 1 to 1,000,000, but only from 1 to 10,000. The only pretext for giving 1,000,000 as the limit is that, of course, two additional figures may be obtained by interpolation; but on this principle ordinary seven-figure tables should be described as extending, not to 100,000, but to 10,000,000.

The first five figures of the logarithms are printed in larger type than, and separated by an interval from, the last two, so that the table may be more conveniently used either as a five- or seven-figure table; the change of figure is denoted by an asterisk prefixed to all the logarithms affected. The figures, though large, are not clear, the appearance of the page being dazzling; the 6's and 9's also seem too large for the other figures, and after all are not very readily distinguishable from the 0's. No differences or proportional parts are given.

Montferrier's Mathematical Dictionary, 1840. Under the Article "Logarithmes," in t. iii. (the supplementary volume) is given a table of four-figure logarithms of numbers from 1000 to 10,000 (pp. 271–279).

In the same volume (p. 252, facing letter L) is given a table of logarithms of the numbers from 1 to 420 to base 2 to five places, the only table of the kind we have met with.

Babbage, 1841. Seven-figure logarithms of numbers from 1 to 1200 and from 10,000 to 108,000, with differences and proportional parts (the last 8000 are given to 8 places). Degrees, minutes, and seconds are also added, but they are divided from the numbers by a thick black line, and are printed in somewhat smaller type, so that they are not so obtrusive as in Callet and others. On the last page there are a few constants.

Great pains were taken with the preparation of this table (which is stereotype), with the view of ensuring the maximum of clearness &c., and with success. The change of figure in the middle of the block is marked by a change in type in the fourth figure in all the logarithms affected. This is, we think, with the exception of the asterisk, the best method that has been used. The chief defect, or rather point capable of improvement, is that the three leading figures in the logarithms are not separated, or in any way distinguished, from the rest of the figures in the block, as is the case in Callet and others. The table was read (wholly or partially) altogether nine times with different tables of logarithms (four of these readings were made after the stereotyping), and is no doubt all but perfectly correct.

One feature of this table is that every last figure that has been increased is marked with a dot subscript.

We know of only two errors: viz., in log 52943 the last figure should be 5 instead of 6; and in log 102467 the last two figures should be 02 instead of 92. The occurrence of the former of these errors is very remarkable, as the logarithm is correct in Vega (folio, 1794), with which the table was read twice (see Sang, 'Athenæum,' June 8, 1872, and Glaisher, 'Athenæum,' June 15, 1872, or 'Journal of the Institute of Actuaries,' July 1872 and January 1873). The latter is given in Gould's (American) 'Astronomical Journal,' vol. iv. p. 48.

Copies of the book were printed on papers of different colours—yellow, brown, green, &c., as it was considered (no doubt justly) that black on a white ground fatigues the eye more than any other combination *. Yellow or light brown seem the colours most preferred by computers, green not being very satisfactory.

In the preface to his tables (1849), Mr. Filipowski writes:—"Babbage's 'Tables of Logarithms,' which probably are the most accurate of all; for, by the aid of his ingenious calculating machine, he was enabled to detect a variety of errors in former tables." This is untrue.

[**Scheutz,** 1857.] Five-figure logarithms, from 1000 to 10,000, calculated and printed by Scheutz's calculating machine: specimens of a few other tables are added. A history and description of the machine &c. is given.

Sang, 1859. Five-figure logarithms, from 1000 to 10,000, arranged as in a seven-figure table; no differences.

Gray, 1865. The table in this tract is rather an auxiliary table to facilitate the calculation of logarithms to twelve places, than a table itself. The tables at the end of the work (see p. 2 of the Introduction) give $\log(1+\cdot001n)$, $\log(1+\cdot001^2n)$, $\log(1+\cdot001^3n)$, from $n=0$ to $n=999$, at intervals of unity, to twelve places. The use of the sequantities in the calculation of logarithms is well-known (see, *e.g.*, Introduction to Shortrede's Tables, vol. i. 1849). Pages 43–55 are occupied with the history of the method, and will be found valuable and interesting. The rest of the book is devoted to explanations &c.

Weddle's method of calculating the logarithms of numbers by resolving them into the reciprocals of series of factors of the form $1-\cdot1^n r$, r being a digit, and then using a subsidiary table of the logarithms of these factors, is fully explained, as also are some improved methods of Mr. Gray's own, depending substantially on the same principle; and all are illustrated with full numerical examples. The whole constitutes the most complete account of the simplest and best of the known methods for the calculation of isolated logarithms that we have met with; and any one engaged on work of this kind would do well to consult it. Of course for calculating a table, the method of differences, as Mr. Gray remarks, is the best. A portion of this tract appeared in the 'Mechanics' Magazine' for 1848; and the whole is reprinted from the 'Assurance Magazine and Journal of the Institute of Actuaries.'

Pineto, 1871. This work consists of three tables; the first (Table auxiliaire) contains a series of factors by which the numbers whose logarithms are required are to be multiplied to bring them within the range of Table 2, and occupies three pages. It also gives the logarithms of the reciprocals of the factors to twelve places. Table 1 merely gives logarithms to 1000, to ten places. Table 2 gives logarithms from 1,000,000 to 1,011,000,

* "Of all the things that are meant to be read, a black monumental inscription on white marble in a bright light is about the most difficult."—De Morgan.

to ten places; the left-hand pages contain the logarithms, and the right-hand pages the proportional parts, which are given for every hundredth of the differences. The change in the line is denoted by an asterisk; and the last figure is underlined when it has been increased.

The mode of using the tables is as follows:—If the first figures of the number lie between 1000 and 1011, the logarithm can be taken out directly from table 2; if not, a factor M is found from the auxiliary table, by which the number must be multiplied in order to make its initial figures lie between these limits, and so bring it within the range of table 2. After performing this multiplication the logarithm can be taken out; and to neutralize the effect of the multiplication, as far as the result is concerned, $\log\left(\frac{1}{M}\right)$ must be added; this quantity is therefore given in an adjoining column to M in the auxiliary table. A similar procedure gives the number answering to any logarithm, only that another factor (approximately the reciprocal of M) is given, so that in both cases multiplication is used.

The laborious part of the work is the multiplication by the factor M; but this is compensated to a great extent by the ease with which, by the proportional parts, the logarithm is taken out. Great pains have been taken to choose the factors M (which are 300 in number) so as to minimize this labour; and of the 300 only 25 consist of three figures all different and not involving 0 or 1. Whenever it was possible, factors containing two figures alike or containing a 0, or of only one or two figures, have been found. The process of taking out a logarithm is rather longer than if VLACQ or VEGA were used; but, on the other hand, the size of this book (only about 80 pp. 8vo) is a great advantage, both of the former works being large folios. Also both Vlacq and Vega are so scarce as to be very difficult to procure; so that Pineto's table will be often the only ten-figure table available for any one who has not access to a good library; and on this account it is unique. Though the principle of multiplying by a factor, which is subsequently cancelled by subtracting its logarithm, is frequently employed in the construction of tables, this is, we believe, the first instance in which it forms part of the process of *using* the table. By taking the numbers to 12 instead of 10 places, in a manner explained in the introduction, greater accuracy in the last place is ensured than results from the use of Vlacq or Vega. It is not stated whether the table is stereotyped; so we presume it is not.

On the last page (p. 56) are given the first hundred multiples of the modulus and its reciprocal to 10 places. (Notices and examples taken from Pineto's tables will be found in the 'Quarterly Journal of Mathematics' for October 1871, and the 'Messenger of Mathematics' for July 1872.)

Sang, 1871. Ten-figure logarithms, from 1 to 1000, and seven-figure logarithms, from 20,000 to 200,000, with differences and multiples (not proportional parts) of the differences throughout.

The advantages arising from the table extending from 20,000 to 200,000, instead of from 10,000 to 100,000, are, that whereas in the latter the differences near the beginning of the table are so numerous that the proportional parts must either be very crowded or some of them omitted, and even if they are all given the interpolation is inconvenient, in a table extending from 20,000 to 200,000 the differences are halved in magnitude, while the number of them in a page is quartered; the space gained enables multiples instead of proportional parts to be given.

The table is printed without rules (except one dividing the logarithms from the numbers); and the numbers are separated from the logarithms by

reversed commas. The absence of rules does not appear to us by any means an unqualified advantage; and a further drawback is that numbers and logarithms are printed in the same type. The change of figure in the line is denoted by an Arabic nokta (a sign like the diamond in a pack of cards); and this, though very clear for 0's, leaves the other figures unchanged, and is greatly inferior in all points of view to the simple asterisk prefixed, or the small figure as used by BABBAGE.

In spite of these drawbacks the table is very convenient, and has advantages possessed by no other, as, in addition to the greater ease with which the interpolations can be performed, greater accuracy is obtained—the last figure being often inaccurate by one or two units in logarithms interpolated from the usual seven-figure tables. We find, however, that computers prefer BABBAGE, except for numbers beginning with 1.

The logarithms of the numbers between 100,000 and 200,000 were calculated *de novo* by Mr. Sang, as if logarithms had never been computed before; and a very full account of the method and manner in which the calculations were performed is given by him in the 'Edinburgh Transactions,' vol. xxvi. pt. iii. (1871). This is the only calculation of common logarithms of numbers since the days of Vlacq, 1628 (except the French manuscript tables).

Two errors in the book (which is stereotyped) were pointed out in the 'Athenæum' for June 8 and 15, 1872, viz. the last figures of log 38962 and 52943 should be 2 and 5 instead of 3 and 6 respectively.

Mr. Peter Gray has kindly communicated to us the following six important errors which have been discovered and communicated to Mr. Sang (or found on revision) and circulated by him in certain later copies of his tables:—

Page 203, log 118536, *for* 9503 *read* 8503
" " log 118537, " 9539 " 8539
" " log 118538, " 9576 " 8576
" 220, log 127340, " 9348 " 9648
" 312, log 173339, " 9863 " 8963
" 354, *for* number 19540 *read* 19440.

The following is a classified list of the tables of logarithms contained in works that are described in § 4:—

Tables of Logarithms of Numbers (to more than 20 places).—SHARP, 1717 [T. IV.] (61 places); SHERWIN, 1741 [T. I.] and [T. II.] (61 places); HOBERT and IDELER, 1799 [T. III.] (36 places); BYRNE, 1849 [T. IV.] (50 places); CALLET, 1853 [T. III.], I. and II. (61 places); HUTTON, 1858, T. 5 and 6 (61 places, early editions only); PARKHURST, 1871, T. II., III., and IX. (102 places), and T. XVIII. (61 places).

(To 20 places) GARDINER, 1742, and (Avignon) 1770 [T. IV.] and [T. V.]; PARKHURST, 1871, T. XIII. and XIV.

(To 15 places) DOUGLAS, 1809, T. IV., Supplement.

(To 11 places) BORDA and DELAMBRE, 1800 or 1801 [T. II.]; KÖHLER, 1848 [T. III.]; CALLET, 1853 [T. II.], I. and II; HOÜEL, 1858, T. V. (table to calculate logarithms); HUTTON, 1858, T. II. and III.

(To 10 places) DE DECKER, 1626 [T. I.]; HENRION, 1626 [T. I.]; VLACQ, 1628 and 1631 [T. I.]; VLACQ, 1633 [T. II.]; VEGA, 1794 [T. I.]; HANTSCHL, 1827, T. IV.; *SALOMON, 1827, T. VIII.; PARKHURST, 1871, T. XII.

(To 8 places) JOHN NEWTON, 1658 [T. I.]; HOÜEL, 1858, T. IV. (table to calculate logarithms); PARKHURST, 1871, T. XXXVII.

(To 7 places) FAULHABER (Logarithmi), 1631; NORWOOD, 1631; ROE, 1633,

T. I.; OUGHTRED, 1657 [T. II.]; Sir J. MOORE, 1681 [T. I.]; VLACQ, 1681 [T. II.]; OZANAM, 1685; GARDINER, 1742, and (Avignon) 1770 [T. I.]; SHERWIN, 1741 [T. III.]; DODSON, 1747, T. XXXII.; HENTSCHEN (VLACQ), 1757 [T. II.]; SCHULZE, 1778 [T. I.]; DONN, 1789, T. I.; TAYLOR, 1792 [T. I.] and [T. II.]; VEGA, 1797, T. I.; VEGA, 1800, T. I.; BORDA and DELAMBRE, 1800 or 1801 [T. I.]; DOUGLAS, 1809 [T. I.], and Supplements; LALANDE, 1829 [T. I.]; HASSLER, 1830 [T. I.]; GRUSON, 1832, T. I.; TURKISH LOGARITHMS (1834); [DE MORGAN] 1839 [T. II.]; FARLEY, 1840, T. II.; HÜLSSE'S VEGA, 1840, T. I.; TROTTER, 1841 [T. IX.]; SHORTREDE (Tables), 1844, T. I.; MINSINGER, 1845 [T. I.]; KÖHLER, 1848 [T. I.]; SHORTREDE, 1849, T. I.; WILLICH, 1853, T. XX.; CALLET, 1853, T. I.; BREMIKER'S VEGA, 1857, T. I.; HUTTON, 1858, T. I.; SCHRÖN, 1860, T. I.; WACKERBARTH, 1867, T. I.; DUPUIS, 1868, T. I. and II.); BRUHNS, 1870, T. I.

(To 6 places) DUNN, 1784 [T. I.]; ADAMS, 1796 [T. I.]; MASKELYNE (Requisite Tables, Appendix), 1802, T. III.; MACKAY, 1810, T. XLV.; WALLACE, 1815 [T. I.]; DUCOM, 1820, T. XXI.; LAX, 1821, T. XVIII.; KERIGAN, 1821, T. X.; RIDDLE, 1824, T. V.; URSINUS, 1827 [T. I.]; GALBRAITH, 1827, T. II.; *SALOMON, 1827, T. VII.; J. TAYLOR, 1833, T. XVIII.; NORIE, 1836, T. XXIV.; JAHN, 1837, Vol. I.; FARLEY, 1840 [T. I.]; TROTTER, 1841 [T. I.]; GRIFFIN, 1843, T. 17; J. TAYLOR, 1843, T. 4; RÜMKER, 1844, T. I.; COLEMAN, 1846, T. XX.; RAPER, 1846, T. I.; DOMKE, 1852, T. XXXII.; BREMIKER, 1852, T. I.; THOMSON, 1852, T. XXIV.; RAPER, 1857, T. 64; BEARDMORE, 1862, T. 36; INMAN, 1871 [T. VII.].

(To 5 places) BATES, 1781 [T. I.]; MASKELYNE (Requisite Tables), 1802, T. XVIII.; BOWDITCH, 1802, T. XVI.; LALANDE, 1805 [T. I.]; RIOS, 1809, T. XV.; MOORE, 1814, T. IV.; DE PRASSE, 1814 [T. I.]; PASQUICH, 1817, T. I.; REYNAUD, 1818 [T. I.]; SCHMIDT, 1821 [T. I.]; STANSBURY, 1822, T. X.; [SCHUMACHER, 1822?], T. V. (arguments in degrees &c.); HANTSCHL, 1827, T. I.; BAGAY, 1829, T. XXIII.; KÖHLER, 1832 [T. I.]; [DE MORGAN], 1839 [T. I.]; GREGORY &c., 1843, T. XI.; MÜLLER, 1844 [T. I.]; STEGMANN, 1855, T. I.; HOÜEL, 1858, T. I.; GALBRAITH and HAUGHTON, 1860 [T. I.], and [T. II.]; *SCHLÖMILCH [1865?]; RANKINE, 1866, T. I.; WACKERBARTH, 1867, T. I.

(To 4 places) [ENCKE, 1828] [T. I.]; [SHEEPSHANKS 1844] [T. I.]; WARNSTORFF'S SCHUMACHER, 1845 [T. III.]; HOÜEL, 1858, T. VI.; ANONYMOUS [1860?] (on a card); OPPOLZER, 1866.

See also SHORTREDE (Comp. Log. Tab.), 1844; PARKHURST, 1871, T. XXVII. and XXVIII.

Art. 14. *Tables of Antilogarithms.*

In the ordinary tables of logarithms the natural numbers are all integers, while the logarithms tabulated are only approximate, most of them being incommensurable. Thus interpolation is in general necessary in order to find the number answering to a given logarithm, even to five figures. It was natural therefore to form a table in which the logarithms were exact quantities, ·00001, ·00002, ·00003 .... to ·99999, &c., and the numbers incommensurable. Few of such tables have been constructed, as for most purposes the ordinary tables are sufficiently convenient, and computers much prefer to have only one work to refer to. The earliest antilogarithmic table is DODSON, 1742; and the only others of any extent are SHORTREDE (1844 and 1849) and FILIPOWSKI (1849), described in § 4. Mr. Peter Gray has a large twelve-figure antilogarithmic table far advanced towards completion; but whether it will be published is uncertain.

Dodson, 1742 (Antilogarithmic Canon). Numbers to eleven places corresponding to logarithms from ·00000 to 1·00000, at intervals of ·00001, arranged like a seven-figure logarithmic table, with interscript differences, and proportional parts at the bottom of the page. The changes in the fourth figure in the middle of the column, both in the numbers and the differences, are marked by points and commas, but not very clearly. There is an introduction of 84 pages; and the tables occupy about 250 pages.

In page ix of the Introduction an extract is given from Wallis, who states that Harriot began, and Warner completed, a table of antilogarithms, which was ready for press fifty years before. This was told Wallis by Dr. Pell, who had assisted Warner in the calculation; and Wallis mentions that he had himself seen the calculation thirty years before, among Harriot's or Warner's papers. Dr. Pell subsequently informed Wallis that the papers were in the hands of Dr. Busby, and that he (Dr. Pell) hoped to publish them shortly. Dr. Pell died in 1685; and at the time Wallis wrote Dr. Busby was also dead, and the printing had not been begun. Speaking of this manuscript De Morgan remarks:—"All our efforts to trace it, by help of published letters &c., lead to the conclusion that, if existing, it must be among Lord Macclesfield's unexamined manuscripts at Shireburn Castle: this is by no means improbable." See, however, some additional information and important remarks by De Morgan, 'Budget of Paradoxes' (1872), pp. 457, 458.

A list of thirty-six errors affecting the first eight figures in Dodson's canon is given by Filipowski in the preface to his 'Antilogarithms' (1849). Mr. Peter Gray ('Insurance Record,' June 9, 1871) says that in 1847 he had collected a list of 125 errors in Dodson; these he communicated to Shortrede, and they were corrected in the plates of his tables (1849). Dodson's work is unique of its kind, and it remained the only antilogarithmic canon for more than a century after its completion, till in 1844 Shortrede published the first edition of his tables; in 1849 he published his second edition; and in the same year Filipowski's tables appeared.

For hyperbolic antilogarithms (viz. e^x and e^{-x}) see under miscellaneous tables (§ 3, art. 25).

The following are antilogarithmic tables described in § 4:—

Antilogarithmic Tables.—Gardiner, 1742, and (Avignon) 1770 [T. VI.] (20 places); Dodson, 1747, T. XXXIII.; [Sheepshanks, 1844] [T. VII.]; Shortrede (Comp. Log. Tab.), 1844; Shortrede (tables), 1844, T. II., and 1849, T. II.; Filipowski, 1849, T. I.; Callet, 1853 [T. II.], III.; Stegmann, 1855, T. II.; Hoüel, 1858, T. VI.; Hutton, 1858, T. IV.; Anonymous [1860 ?] (on a card); Parkhurst, 1871, T. XXVII., XXVIII., and XXXV.

Art. 15. *Tables of (Briggian) Logarithmic Trigonometrical Functions.*

A general account of the introduction of Briggian logarithms is given in § 3, art. 13; and Napier's 'Canon Mirificus' (1614), containing a Napierian logarithmic canon, is described in § 3, art. 17. The first table of decimal logarithms of numbers was published by Briggs in 1617, and the first (decimal) logarithmic canon by Gunter in 1620 (see below), giving the results to 7 places. The next calculation was by Vlacq, who appended to his 'Centum Chiliades' in the 'Arithmetica' of 1628 a minute logarithmic canon to 10 places, obtained by calculating the logarithms of the sines &c. of Rheticus. After the publication of his 'Arithmetica' in 1624, Briggs devoted himself to the calculation of logarithmic sines &c., and at his death in 1631 had all but completed a ten-decimal canon to every hundredth of a

degree. This was published by Vlacq at his own expense at Gouda in 1633, under the title 'Trigonometria Britannica' (see below): the introduction was written by Gellibrand, by whose name the book is sometimes cited. In the same year VLACQ published his 'Trigonometria Artificialis,' containing a ten-second canon to ten decimals. GUNTER's original table contains a good many errors in the last figures; and a very slight comparison shows whether any particular table was copied from GUNTER or VLACQ; HENRION, 1626, and DE DECKER, 1626 (§ 4), are from the former, FAULHABER (§ 4), 1631, from the latter. Briggs appreciated clearly the advantages of a centesimal division of the quadrant, and, by taking a hundredth of a degree instead of a minute, made a step towards a reformation in this respect; and Hutton has truly remarked that, but for the appearance of VLACQ's work, the decimal division of the degree might have become recognized, as is the case with the corresponding division of the second*.

The next great advance on the 'Artificialis' was more than a century and a half afterwards, when MICHAEL TAYLOR (1792) published his seven-decimal canon to *every second* (§ 4). On account of its great size, and for other reasons, it never came into very general use, BAGAY's 1829 (§ 4) being preferred; the latter is now, however, very difficult to procure. The only other canon to every second we have seen or heard of is SHORTREDE's, 1844 and 1849 (§ 4), which is the most complete as regards proportional parts &c. that we know of. The canon is in modern editions issued separately.

Lalande ('Encyclopédie Méthodique. Mathématiques,' Ast. Tables) states that in April 1784 he received from M. Robert, curé of St. Geneviève at Toul, a volume of sines for every second of the quadrant, and soon after the tangents; but he had heard that TAYLOR, in England, was engaged in publishing log sines and cosines to every second, and that the Board of Longitude had contributed £300 to the expense. These volumes were purchased by Babbage at the sale of Delambre's library, and they appear in the Babbage Catalogue (only the title of the table of sines is given; but it is to be presumed that the library contains both, as two volumes are spoken of). Babbage lent them in 1828 to the Board of Longitude; and some errata in TAYLOR, 1792, were found by means of them. [They are now (1873) in the possession of Lord Lindsay, who has purchased the whole of Mr. Babbage's mathematical library.]

No ten-decimal canon to every second has been calculated. The French manuscript tables are described in § 3, art. 13. Of logarithmic trigonometrical canons that have appeared the number is very great. We may especially mention CALLET, 1853; BREMIKER's VEGA, 1857; HUTTON, 1858; SCHRÖN, 1860; DUPUIS, 1868; and BRUHNS, 1870.

* The centesimal division of the degree is of paramount importance, whereas the centesimal division of the right angle is of next to none at all; and had the French mathematicians at the end of the last century been content with the former, it is not unlikely that their tables would have superseded the sexagesimal ones still in use, instead of having been almost totally ignored by computers. The hundredth part of a right angle is almost as arbitrary a unit as the ninetieth; and no advantage (but on the contrary great inconvenience) would result from the change; but to divide the nonagesimal degree into centesimal minutes, and these into centesimal seconds, &c., in other words to measure angles by degrees and decimals of a degree, would ensure all the advantages of a decimal system (a saving of work in interpolations, multiplications, &c.). This Briggs and his followers, Roe, Oughtred, John Newton, &c., perceived and acted upon two hundred and fifty years ago; and they seem to have shown a truer appreciation of the matter than did the French mathematicians. It may be taken for granted that the magnitude of the degree will never be altered; but there is no reason why sexagesimal minutes and seconds should not be replaced by decimals of a degree; and this is a change which might, and we hope will hereafter be made.

The chief tables in which the angle is divided completely centesimally are Callet 1853, Borda and Delambre, and Hobert and Ideler.

For the meaning of S and T (Delambre's tables), see § 3, art. 13, near the end of the introductory remarks.

Gunter, 1620. Log sines and tangents for every minute of the quadrant (semiquadrantally arranged) to 7 places. This is the first (Briggian) logarithmic trigonometrical canon calculated or published. The book is extremely scarce; and we have only seen one copy of it, viz. that in the British Museum, where it is bound up with Briggs's 'Logarithmorum Chilias Prima.' There is engraved on the titlepage a diagram of a spherical triangle, S P Z. De Morgan (who had never seen a copy) says that it also contains logarithms of numbers as far as 1000; but this is not correct. The British-Museum copy has written in ink on the titlepage, "Radius autem verus est 10,000,000,000." This has reference to the fact that the logarithm of the radius is taken to be 10, and is true in one sense, but not in the usual one, which is that, this being the radius, the sines &c. are true to the nearest unit. Custom has very properly decided to consider the radius of a logarithmic canon the same as what would be the radius of the resulting natural canon if the logarithms were replaced by their numbers. We have not seen the second edition, in which no doubt the logarithms of numbers mentioned by De Morgan were added; or it is *just possible* that some copies of Briggs's 'Chilias' (1617) were issued with the 'Canon,' both being bound together in the copy we have seen, and that this has given rise to the assertion. Gunter's 'Canon' was also issued under an English title, 'A Canon of Triangles,' &c. (Bodleian Catalogue): see Phil. Mag. (Suppl. No.) Dec. 1872. For a life of Gunter, see Ward's 'Lives of the Professors of Gresham College,' pp. 71–81.

Briggs, 1633 ('Trigonometria Britannica'). Natural sines (to 15 places) and tangents and secants (to 10 places), also log sines (to 14 places) and tangents (to 10 places), at intervals of a hundredth of a degree from 0° to 45°, with interscript differences for all the functions. The division of the degree is thus centesimal; but the corresponding arguments in minutes and seconds are also given, the intervals so expressed being 36″.

This table was calculated by Briggs; but he did not live to publish it. The trigonometry is by Gellibrand.

Gunter, 1673. At the end of the work is given a table of log sines and tangents for every minute of the quadrant to 7 places, followed by seven-figure logarithms of numbers to 10,000.

The table of log sines &c. is printed as it appeared in Gunter's 'Canon Triangulorum,' 1620, as the last figures in very many instances differ from the correct values, which were first given by Vlacq in the 'Arithmetica' &c. (1628).

This is the fifth edition of Gunter's works; but we remember to have seen it stated somewhere that the works themselves (separate) were regarded as the first edition in this enumeration.

Berthoud, 1775. At the end of the 'Recueil des Tables nécessaires pour trouver la longitude en mer,' is a table of log sines to every minute of the quadrant to 6 places (pp. 25–34).

Callet, 1827 ('Log Sines &c.'). Log sines and tangents for every second to 5°, and log sines, cosines, tangents, and cotangents from 0° to 45°, at intervals of ten seconds, with differences, all to seven places.

These are the same as CALLET 1853 [T. IX. and X.] (§ 4), and were published separately, De Morgan states, to accompany Babbage's logarithms of numbers; they are in consequence printed on yellow paper; but it is, both in colour and texture, very inferior to that used by Babbage.

Airy, 1838. Log sines and cosines from 0^h to 24^h, at intervals of 10^s to 5 places. The proper sign is prefixed to each quantity: no differences. The sines are on the left-hand pages, the cosines on the right-hand. As was remarked by De Morgan, this is an eightfold repetition of one table: it occupies 48 pp. The table is improperly described as having been "*computed* under the direction" &c.: it is, of course, only a simple rearrangement.

The following is a complete classified list of tables on the subject of this article contained in the works that are described in § 4, with several other lists appended.

Log sines, tangents, secants, and versed sines.—(To 7 places) WILLICH, 1853, T. *B*; HUTTON, 1858, T. IX.

(To 5 places) RIOS, 1809, T. XVI. (also log coversed &c.).

Log sines, tangents, and secants.—(To 10 places) VLACQ, 1628 and 1631 [T. II.]; FAULHABER (Canon), 1631.

(To 7 places) Sir J. MOORE, 1681 [T. III.]; SHERWIN, 1741 [T. IV.]; BORDA and DELAMBRE, 1800 or 1801, T. VI. (centesimal); DOUGLAS, 1809 [T. II.].

(To 6 places) DUNN, 1784 [T. II.]; ADAMS, 1796 [T. II.]; WALLACE, 1815 [T. II.]; J. TAYLOR, 1833, T. XIX.; NORIE, 1836, T. XXV.; TROTTER, 1841 [T. III.]; GRIFFIN, 1843, T. 18; J. TAYLOR, 1843, T. 5; RÜMKER, 1844, T. II.; COLEMAN, 1846, T. XXIII.; RAPER, 1846, T. IV.; DOMKE, 1852, T. XXXV.; RAPER, 1857, T. 68; INMAN, 1871 [T. IV.].

(To 5 places) MASKELYNE (Requisite Tables), 1802, T. XIX.; BOWDITCH, 1802, T. XVII.; MOORE, 1814, T. V.; GALBRAITH, 1827, T. V.; GREGORY &c., 1843, T. IX.; HOÜEL, 1858, T. II.

(To 4 places) GORDON, 1849, T. IX. (cosecants).

Log sines and tangents (only).—(To 11 places) BORDA and DELAMBRE, 1800 or 1801 [T. III.] (centesimal), and [T. V.] (logarithmic differences of sines and tangents).

(To 10 places) VLACQ, 1633 [T. I.]; ROE, 1633, T. I. (centesimal division of the degree); VEGA, 1794, T. II.

(To 8 places) JOHN NEWTON, 1658 [T. II.] and [T. III.] (arguments partly centesimal).

(To 7 places) DE DECKER, 1626 [T. II.]; HENRION, 1626 [T. II.]; NORWOOD, 1631; VLACQ, 1681 [T. I.]; OZANAM, 1685; GARDINER, 1742, and (Avignon), 1770 [T. II.]; DODSON, 1747, T. XXXIV.; HENTSCHEN (VLACQ), 1757 [T. I.]; SCHULZE, 1778 [T. III.] and [T. V.]; DONN, 1789, T. III.; TAYLOR, 1792 [T. III.]; VEGA, 1797, T. II.; LAMBERT, 1798, T. XXVI.; HOBERT and IDELER, 1799 [T. I.] (centesimal); VEGA, 1800, T. II.; (?) *SALOMON, 1827, T. IX.; BAGAY, 1829, Appendix; LALANDE, 1829 [T. II.]; HASSLER, 1830 [T. II.–IV.]; GRUSON, 1832, T. VII.; TURKISH LOGARITHMS [1834]; HÜLSSE'S VEGA, 1840, T. II.; SHORTREDE (Tables), 1844, T. III., and 1849, Vol. II.; KÖHLER, 1848 [T. IV.]; CALLET, 1853 [T. VI.] (centesimal), [T. IX.] and [T. X.]; BREMIKER'S VEGA, 1857, T. II. and III.; HUTTON, 1858, T. VIII.; SCHRÖN, 1860, T. II.; DUPUIS, 1868, T. VI., VII., and VIII.; BRUHNS, 1870, T. II. and III.

(To 6 places) OUGHTRED, 1657 [T. I.] (centesimal division of degree); DUCOM, 1820, T. IX.; URSINUS, 1827 [T. II.] and [T. V.]; J. TAYLOR, 1833,

T. XIX.; NORIE, 1836, T. XXV.; JAHN, 1837, Vol. II.; FARLEY, 1840 [T. II.]; J. TAYLOR, 1843, T. 5; RÜMKER, 1844; DOMKE, 1852, T. XXXIV.; BREMIKER, 1852, T. II.

(To 5 places) BATES, 1781 [T. II.]; LALANDE, 1805, T. II.; DE PRASSE, 1814 [T. II.]; PASQUICH, 1817, T. II.; REYNAUD, 1818 [T. II.]; SCHMIDT, 1821 [T. II.]; KÖHLER, 1832 [T. II.]; [DE MORGAN], 1839 [T. III.]; GALBRAITH and HAUGHTON, 1860 [T. III.]; WACKERBARTH, 1867, T. III.

(To 4 places) [ENCKE, 1828] T. II.; BEVERLEY (1833?), T. XVII.; MÜLLER, 1844 [T. IV.]; [SHEEPSHANKS, 1844] [T. III.]; WARNSTORFF'S SCHUMACHER, 1845 [T. IV.]; THOMSON, 1852, T. XVI.; OPPOLZER, 1866; PARKHURST, 1871, T. XXX. and XXXI.

(Miscell.) SHORTREDE (Comp. Log. Tab.) 1844.

Log sines and secants (only).—(To 5 places) STANSBURY, 1822, T. *H.*

Log sines (alone)* (for small arcs, sines = tangents).—(To 7 places) GARDINER, 1742 [T. II.], and (Avignon) 1770 [T. II.]; HÜLSSE'S VEGA, 1840, T. II.; KÖHLER, 1848 [T. IV.].

(To 6 places) MACKAY, 1810, T. XLVI.; KERIGAN, 1821, T. VIII.; HANTSCHL, 1827, T. II.; FARLEY, 1840 [T. III.]; RAPER, 1846, T. III.; RAPER, 1857, T. 66 and 67; BEARDMORE, 1862, T. 37; INMAN, 1871 [T. III.].

(To 5 places) [SCHUMACHER, 1822?] T. VI.; [DE MORGAN] 1839 [T. IV.]; RAPER, 1846, T. II.; THOMSON, 1852, T. XII.

(To 4 places) [SHEEPSHANKS, 1844] [T. II.]; PARKHURST, 1871, T. XXXVIII.

(Expressed otherwise) ACADÉMIE DE PRUSSE, 1776 [T. I.]; CALLET, 1853 [T. VII.] (centesimal) (15 places).

Log tangents (alone)* (for small arcs, sines = tangents).—(To 7 places) GARDINER (Avignon), 1770 [T. II.].

(To 6 places) MACKAY, 1810, T. XLVII.; HANTSCHL, 1827, T. III.

Log versed sines (alone).—(To 7 places) Sir J. MOORE, 1681 [T. IV.]; [Sir J. MOORE, 1681, versed sines]; DOUGLAS, 1809 [T. IV.]; FARLEY, 1856 [T. II.].

(To 6 places) RÜMKER, 1844, T. IV.

(To 5 places) KERIGAN, 1821, T. XI.; J. TAYLOR, 1833, T. XXI., and 1843, T. 30.

(To 4 places) DONN, 1789, T. V.

Note.—Log rising (in nautical tables) = log versed sine. See next page.

Log secants (alone).—(To 5 places) THOMSON, 1852, T. XI.

Miscellaneous.—Log sec x, $\frac{1}{2}$ log sec x, and $\frac{1}{2}$ log sin x, CROSWELL, 1791, T. I.; log diff. sin., BORDA and DELAMBRE, 1800 or 1801 [T. V.] (centesimal); log $\frac{1}{2}$ $(1 \pm \cos x)$, log $\frac{1}{2}$ $(1 \pm \sin x)$ &c., RIOS, 1809, T. XVI.; log tan $\frac{x}{2}$, STANSBURY, 1822, T. *D*; log $\frac{1}{2}$ $(1 - \cos x)$ &c., STANSBURY, 1822, T. *H.*; log $\frac{1}{2}$ $(1-\cos x)$, NORIE, 1836, T. XXXI.; log $\frac{1}{2}$ $(1-\cos x)$, COLEMAN, 1846, T. XXI.; log $\frac{1}{2}$ $(1-\cos x)$, GORDON, 1849, T. XVIII.; log $\frac{1}{2}$ $(1-\cos x)$, THOMSON, 1852, T. XIII.; log cosec x—·54000, THOMSON, 1852, T. XV.; log sin $\frac{x}{2}$, THOMSON, 1852, T. XXIII.; log $\frac{1}{2}$ $(1-\cos x)$, RAPER, 1857, T. 69; $\frac{1}{2}$ log $\frac{1}{2}$ $(1-\cos x)$ and log $\frac{1}{2}$ $(1-\cos x)$, INMAN, 1871, T. V. and VI.

The following are tables generally met with in nautical collections:—

Log sines, tangents, and secants to every quarter-point.—(To 7 places)

* Tables of sines and tangents are not unfrequently printed with the sines on the versos and the tangents on the rectos of the leaves, or *vice versâ*, so that practically they are separated; but in such cases the table has usually been regarded merely as one of sines and tangents.

NORIE, 1836, T. XXIII.; SHORTREDE (Tables), 1844, T. V.; DONN, 1789, T. II. (sines and cosecants only).

(To 6 places) RIDDLE, 1824, T. IV.; GALBRAITH, 1827, T. IV.; J. TAYLOR, 1833, T. XVII.; TROTTER, 1841 [T. II.]; GRIFFIN, 1843, T. 16; J. TAYLOR, 1843, T. 3; COLEMAN, 1846, T. XIX.; DOMKE, 1852, T. XXXII.; RAPER, 1857, T. 65.

(To 5 places) ADAMS, 1796 [T. III.]; BOWDITCH, 1802, T. XVI.; MOORE, 1814, T. III.

Log. ½ elapsed time, mid time, and rising.—(To 5 places) DONN, 1789, T. IV.; MASKELYNE (Requisite Tables), 1802, T. XVI.; BOWDITCH, 1802, T. XIII.

The three Tables are separated in the following:—(To 5 places) MACKAY, T. XLVIII.–L.; MOORE, 1814, T. XXIII.; NORIE, 1836, T. XXVII.–XXIX.; DOMKE, 1852, T. XXXVII.–XXXIX.

We have thought it worth while to collect into one list below all the tables, giving log sines &c. to every second. It must be particularly noticed, however, that in the great majority of cases only the functions for the first few degrees of the quadrant are given to every second in the tables referred to, which should in all cases be sought in § 4.

Tables of logarithmic trigonometrical functions to seconds.—GARDINER, 1742 [T. II.], and (Avignon) 1770 [T. II.]; SCHULZE, 1778 [T. III.]; TAYLOR, 1792, T. III. (for the whole quadrant); VEGA, 1794, T. II.; VEGA, 1797, T. II.; VEGA, 1800, T. II.; DUCOM, 1820, T. IX.; KERIGAN, 1821, T. VIII.; [SCHUMACHER, 1822 ?] T. VI.; *SALOMON, 1827, T. IX.; BAGAY, 1829, Appendix (for the whole quadrant); HASSLER, 1830 [T. II.]; JAHN, 1837, Vol. II.; [DE MORGAN] 1839 [T. IV.]; HULSSE's VEGA, 1840, T. II.; MÜLLER, 1844 [T. IV.]; SHORTREDE (Tables), 1844, T. III. and 1849, Vol. II. (for the whole quadrant); RAPER, 1846, T. II.; KÖHLER, 1848 [T. IV.]; DOMKE, 1852, T. XXXIV.; BREMIKER, 1852, T. II.; CALLET, 1853 [T. IX.]; BREMIKER's VEGA, 1857, T. II.; RAPER, 1857, T. 66; HUTTON, 1858, T. VIII.; WACKERBARTH, 1867, T. III.; DUPUIS, 1868, T. VI. and VII.; BRUHNS, 1870, T. II.; INMAN, 1871 [T. III.] and [T. VIII].

We have formed the following lists of tables in § 4, which (not only in the same work, but side by side in the same table) give both natural and logarithmic functions:—

Tables containing both natural and logarithmic functions (in the same table).—(To 15 places) CALLET, 1853 [T. VII.] (centesimal).

(To 7 places) Sir J. MOORE, 1681 [T. III.]; VLACQ, 1681 [T. I.]; OZANAM, 1685; SHERWIN, 1741 [T. IV.] and [T. V.]; HENTSCHEN (VLACQ), 1757 [T. I.]; SCHULZE, 1778 [T. V.]; DONN, 1789, T. III.; LAMBERT, 1798, T. XXVI.; HOBERT and IDELER, 1799 [T. I.] (centesimal); WILLICH, 1853, T. *B*; HUTTON, 1858, T. IX.

(To 6 places) OUGHTRED, 1657 [T. I.]; URSINUS, 1827 [T. V.].

(To 5 places) HOÜEL, 1858, T. II.

(To 4 places) DONN, 1789, T. V.

(Mixed) BATES, 1781 [T. II.].

Natural and log versed sines (in the same table).—(To 7 places) Sir J. MOORE, 1681 [T. IV.]; [Sir J. MOORE, 1681, versed sines]; SHERWIN, 1741 [T. V.]; DOUGLAS, 1809, T. IV.

Art. 16. *Tables of Hyperbolic Logarithms (viz. logarithms to base 2·71828. . .).*

The logarithms invented by NAPIER, and explained in the 'Descriptio' (1614) and 'Constructio' (1619) (see § 3, art. 17), were not the same as

those now called *hyperbolic* (viz. to base e) and very frequently also *Napierian* logarithms. It is also to be noticed that Napier calculated no logarithms of numbers. John Speidell, 1619 (see below), first published logarithms to base e both of numbers and sines. The most complete table of hyperbolic logarithms is Dase's, described below, which could be used, though not so conveniently, as an ordinary seven-figure Briggian table extending from 1000 to 105,000. It would sometimes be useful to have also a complete seven-place table of hyperbolic logarithms of numbers from 1000 to 100,000, exactly similar to the corresponding Briggian tables, as in some cases it is convenient to perform calculations in duplicate, first by Briggian, and then by hyperbolic logarithms; and such a table would be of use in multiplying five figures by five figures: but hyperbolic logarithms cannot be rendered convenient for general purposes.

The most elaborate hyperbolic logarithmic table is Wolfram's, which practically gives the hyperbolic logarithms of all numbers from unity to 10,000 to *forty-eight decimal places*. It first appeared, we believe, in Schulze (§ 4), and was reprinted in Vega, folio, 1794 (§ 4).

Wolfram was a Dutch lieutenant of artillery; and his table represents six years of very laborious work. Just before its completion he was attacked by a serious illness; and a few logarithms were in consequence omitted in Schulze (see Introduction, last page but two, to vol. i. of Schulze). The omissions were supplied in Vega's 'Thesaurus,' 1794. De Morgan speaks of Wolfram's table as one of the most striking additions that have been made in the subject of logarithms in modern times.

Montucla ('Histoire,' vol. iii. p. 360) states that in 1781 Alexander Jombert proposed to publish by subscription new tables of hyperbolic logarithms to 21 places for all prime numbers to 100,000, with a table of all odd numbers of two factors to the same limit. The author was Dom Valleyre, advised by Dom Robé, benedictine of St. Maur. Only two hundred subscribers were required before the commencement of the printing, and nothing was asked in advance; but the project fell through, no doubt for want of subscribers. We infer from this account that the table was calculated.

The Catalogue of the Royal Society's Library contains, under the name of Prony, the title, "Formules pour calculer l'effet d'une machine à vapeur à détente et à un seul cylindre.....Tables de logarithmes hyperboliques calculées de 100^e en 100^e d'unité, fol. lithog.," but without any reference to the place where the book is to be found in the library, so that we have not seen it.

Speidell, 1619. Logarithmic sines, tangents, and secants, semiquadrantally arranged, to every minute, to five places. The logarithms are hyperbolic (viz. to base e), and the first of the kind ever published. When the characteristic is negative Speidell adds 10 to it, and does not separate the characteristic so increased from the rest of the figures by any space or mark. Thus he prints the logarithm of the sine of 21° 30′ as 899625, its true value being $\bar{2}{\cdot}99625$; but the logarithm of the cotangent is given as 93163; it would now be written ·93163. The Royal Society has "the 5-impression, 1623," with the "Breefe Treatise of Sphæricall Triangles" prefixed, and also some ordinary hyperbolic logarithms of numbers (the first published) &c. On this see De Morgan's long account of Speidell's works, who, however, had never seen the edition of 1619, in which the canon occurs by itself without the logarithms of numbers. We cannot enter into the question of Speidell's fairness here. The 1619 copy we have seen (Cambridge Univ. Lib.) has an obliteration where, in the 1623 copy, there occur the words "the 5-impression."

Rees's Cyclopædia, 1819 (Art. "Hyperbolic Logarithms," vol. xviii.). Hyperbolic logarithms (to 8 places) of all numbers from 1 to 10,000, arranged in groups of five.

The table was calculated by Barlow, and appears also in his mathematical tables (1814).

Dase, 1850 (Hyperbolic Logarithms). Hyperbolic logarithms, from ·1 to 1000, at intervals of unity, and from 1000·0 to 10500·0 at intervals of 0·1 to seven places, with differences and proportional parts, arranged as in an ordinary seven-figure table. The change of figure in the line is denoted by an asterisk prefixed to all the numbers affected. The table is a complete seven-place table, as by adding log 10 to the results the range is from 10,000 to 105,000 at intervals of unity. The table appeared in the 34th part (new series, t. xiv.) of the 'Annals of the Vienna Observatory' (1851); but separate copies were printed, in the preface to which Dase gave six errata. This portion of the preface is reproduced in the introduction by Littrow to the above volume of 'Annals.' The table was calculated to ten places, and three rejected. It was the author of this table who also computed the factorial tables (§ 3, art. 8), and calculated the value of π correctly to 200 decimal places (Crelle's Journal, t. xxvii. p. 198).

Filipowski, 1857. Hyperbolic logarithms, from 1 to 1201, to 7 places, are appended to Mr. Filipowski's English edition of Napier's 'Canon Mirificus.'

The following is a list of references to § 4 :—

Hyperbolic logarithms of numbers.—(To 48 places) Schulze, 1778 [T. II.]; Vega, 1794 [T. III.]; Callet, 1853 [T. III.], I., and II.

(To 25 places) Lambert, 1798, T. XVI.

(To 20 places) Callet, 1853 [T. II.], I. and II.

(To 11 places) Borda and Delambre, 1800 or 1801 [T. IV.].

(To 10 places) *Salomon, 1827, T. VIII.

(To 8 places) Vega, 1797, Vol. II. T. II.; Barlow, 1814, T. VI.; Hantschl, 1827, T. VI.; Hülsse's Vega, 1840, T. VI.; Trotter, 1841 [T. XI.]; Köhler, 1848, T. I.

(To 7 places) Gardiner (Avignon), 1770 [T. VII.]; Lambert, 1798, T. XIII.–XVI.; Willich, 1853, T. *A*; Hutton, 1858, T. V. and VI.; Dupuis, 1868, T. III.

(To 5 places) Rankine, 1866, T. 3; Wackerbarth, 1867, T. V.

See also *Schlömilch [1865 ?].

Art. 17. *Napierian Logarithms* (*not to base* 2·71828....).

The invention of logarithms has been accorded to Napier of Merchiston with a unanimity not often met with in reference to scientific discoveries. The only possible rival is Justus Byrgius, who seems to have constructed a rude kind of logarithmic table; but there is every reason to believe that Napier's system was conceived and perfected before Byrge's in point of time; and in date of publication Napier has the advantage by six years. Further, Byrge's system is greatly inferior to Napier's; and to the latter alone is the whole world indebted for the knowledge of logarithms, as (with the exception of Kepler, one of the most enthusiastic of the contemporary admirers of Napier and his system, who does allude to Byrge) no one ever suggested any one else as having been the author whence they had drawn their information, or as having anticipated Napier at all, till the end of the last century, when Byrge's claim was first raised, though his warmest advocates always assigned far the greater part of the credit of the invention to Napier.

On Byrge's claim see De Morgan's careful résumé (article "Tables," under Justus Byrgius, 1620, in the 'Eng. Cyclop.,' where references are given), and Mr. Mark Napier's 'Memoirs of John Napier of Merchiston,' Edinburgh, 1834 (where the question how far Napier received any assistance from his predecessors in the discovery is fully discussed). We have also seen 'Justus Byrg als Mathematiker und dessen Einleitung in seine Logarithmen,' by Dr. Gieswald, Dantzig, 1856, 4to (pp. 36). Napier's 'Canonis Logarithmorum Mirifici Descriptio' (which contained the first announcement and the first table of logarithms) was published in 1614; and in 1619 (two years after his death, which occurred on April 4, 1617) appeared the 'Mirifici logarithmorum Canonis Constructio,' edited by his son Robert, in which the method of constructing the canon is explained. The various reprints and translations of the 'Descriptio' and 'Constructio' are described under Napier, 1614 and 1619; and the relations between Napier and Briggs with regard to the invention of decimal logarithms are noticed in § 3, art. 13. The most elaborate canon of *Napierian* logarithms is Ursinus (1624–1625), described below.

The difference between the logarithms introduced Napier and hyperbolic logarithms is explained under Napier (1614). We have paid considerable attention to the early logarithmic tables, and have examined all of them that were accessible to us; and it is with some regret that we omit to notice them in detail here: the accounts of the smaller tables that immediately succeeded Napier would be of only bibliographical or historical interest; and to describe them with sufficient detail to render the accounts of value would occupy too much space. However, as the works of this period are very rare, it is worth while remarking that there is a copy of Napier's 'Constructio' in the Cambridge University Library (there is none in the British Museum or Royal Society's Library), where also are to be found Ursinus's 'Cursus' of 1618, Speidell 1619, and Kepler 1624: we have generally, in describing works of this date, mentioned the library containing the copy we have seen. We have found De Morgan to be very accurate (except where he has had to form his opinions from secondhand or imperfect evidence); and he has devoted much care to the early logarithmic tables, so that we feel the less reluctance in omitting to notice them further here.

Napier, 1614. The book consists of 57 pp. explaining the nature of logarithms &c., and 90 pp. of tabular matter, giving natural sines and their *Napierian* logarithms to every minute of the quadrant (semiquadrantally arranged) to seven or eight figures (seven decimals). Logarithmic tangents are also given under the heading *differentiæ* (they are the differences between the sine and cosine, which, though the latter name is not used, are both on the same line, as a consequence of the semiquadrantal arrangement of the table).

The logarithms introduced by Napier were not hyperbolic or Napierian logarithms as we now understand these terms, viz. logarithms to the base e (2·71828..), but somewhat different; the relation between the two being

$$e^l = 10^7 e^{-\frac{L}{10^7}}, \text{ or } L = 10^7 \log_e 10^7 - 10^7 l,$$

l being the logarithm to base e, and L the *Napierian* logarithm; the relation between N (a sine) and L, its *Napierian* logarithm is therefore

$$N = 10{,}000{,}000\, e^{-\frac{L}{10{,}000{,}000}};$$

the logarithms therefore decrease as the sines increase. A brief explanation of the principle of Napier's own method is given by Professor Wackerbarth in vol. xxxi. p. 263 (1871) of the 'Monthly Notices of the Royal Astronomical Society.' The author of that communication there points out that the description in most elementary books of Napierian logarithms, as logarithms to the base e, is incorrect; but this criticism appears to us irrelevant, as by calling certain logarithms Napierian it is not asserted that they are used at present in the exact form in which they were presented by Napier. A glance at the formula written above shows that all the essential features of logarithms to the base e are contained in Napier's system, and that there is no impropriety in calling the former by his name. De Morgan says that "Delambre proposed to call them [Napier's logarithms] *Napierian* logarithms, and to restrict the term hyperbolic to the modern or e logarithms; but custom has refused,"—and no doubt very properly, as, except in mathematical histories &c., there is no occasion to distinguish the two systems from one another. For our own part, we should much prefer to see *natural* or *hyperbolic* and *common* logarithms universally called *Napierian* and *Briggian*, after the two great founders of logarithmic tables.

A translation of Napier's 'Canon Mirificus' was made by Edward Wright (well known in connexion with the history of navigation), and, after his death, published by his son at London in 1616, under the title "A Description of the admirable Table of Logarithmes, &c." (12mo). On account of the rarity of this work and the 'Constructio,' the full titles of both are given in § 5. There is a short "Preface to the Reader" by Briggs, and a description of a triangular diagram invented by Wright for finding the proportional parts. Napier's table, however, is printed to one figure less than in the 'Canon Mirificus' throughout. The edition was revised by Napier himself. On Wright, see Introduction to Hutton's 'Mathematical Tables.' The 'Canon Mirificus' was also reprinted by Maseres in the sixth volume of the 'Scriptores Logarithmici' (1791–1807); and in 1857 Mr. Filipowski published at Edinburgh a translation of the same work (full title given in § 5; the tone of the Introduction renders any comment on it unnecessary).

Both the 'Descriptio' (the 'Canon Mirificus') and the 'Constructio' were reprinted by Bartholomew Vincent at Lyons in 1620 (who thus first published logarithms on the Continent), the title of the former appearing on the titlepage as "Logarithmorum Canonis Descriptio, seu Arithmeticarum supputationum mirabilis abbreviatio. Ejusque usus in utraque Trigonometria ut etiam in omni Logistica Mathematica, amplissimi, facillimi & expeditissimi explicatio. Authore ac Inventore Joanne Nepero, Barone Merchistonii, &c., Scoto. [Printer's device with word *Vincenti.*] Lugduni. Apud Barth. Vincentium, M.DC.XX. Cum privilegio Cæsar. Majest. & Christ. Galliarum Regis." The full title of Napier's original edition of 1614 is given in § 5; and it will be seen that it is very different from that written above. Very many writers (including Montucla) give the title of Vincent's reprint as that of the original work. There is an imperfect copy of Vincent's reprint, containing only the 'Descriptio' (the 'Constructio' having been torn out), in the British Museum; but the Royal Society has a perfect copy. Wright's translation of 1616 is in the British Museum.

On the accuracy of Napier's Canon see Delambre, 'Astron. Mod.,' t. i. p. 501. Mr. Mark Napier's 'Memoirs of John Napier' gives nearly all that is known with regard to Napier's life, MSS., &c.; but it is told in a verbose and diffuse manner, and written in a partisan spirit as regards Briggs.

A manuscript on arithmetic and algebra, written by Napier and left by

him to Briggs, was privately printed in 1839, under the title "De Arte Logistica Joannis Naperi Merchistonii Baronis libri qui supersunt," edited by Mr. Mark Napier. An historical sketch, mainly derived from the same author's 'Memoirs,' is prefixed. In 1787 was also published 'An account of the Life, Writings, and Inventions of John Napier of Merchiston,' by David Stewart, Earl of Buchan, and Walter Minto, LL.D. Perth, 4to. See also Phil. Mag. Suppl. No., December, 1872, "On some early Logarithmic Tables." Leslie ('Philosophy of Arithmetic,' 2nd edit., 1820, p. 246) describes Napier's work as "a very small duodecimo;" the last word should be "quarto." The page is 7·7 inches by 5·7 inches.

We may remark that Napier's name is spelt in a variety of ways; we have seen Neper, Naper, Nepair, and Nepper. He always Latinized his name into Neperus or Naperus, but spelt it in the vernacular several ways. The family now write the name Napier; and this spelling is generally adopted, and with good reason.

Napier, 1619 ('Constructio'). This work contains no table, and is therefore not properly included in this Report. We have, however, noticed it on account of its being a sequel to the 'Descriptio,' and also on account of its rarity (the full title is given in § 5). The only copy we have seen (in the Cambridge University Library), which belonged to Oughtred, contains two titlepages, the first running "Mirifici logarithmorum canonis descriptio.... accesserunt opera posthuma; primo, Mirifici ipsius canonis constructio.... Edinburgi....1619," and the second being as given in § 5. From this we infer that a reprint of the 'Descriptio' (1619) was prefixed to the 'Constructio,' but that it was torn out from the copy we have examined.

On the reprints, &c. of the 'Constructio,' see under NAPIER, 1614.

Ursinus, 1624–1625. A canon exactly similar to NAPIER's in the 'Canon Mirificus,' 1614, only much enlarged. The intervals of the arguments are 10″; and the results are given to eight places: in NAPIER's canon the intervals are 1′, and the number of places is 7. The logarithms are strictly *Napierian*, and the arrangement is identical with that in the canon of 1614. This is the largest *Napierian* canon that has been calculated. The copy we have seen is in the British Museum. In 1618 Ursinus published his 'Cursus Mathematicus,' of which there is a copy in the Cambridge University Library.

The only table of Napierian logarithms described in § 4 is SCHULZE, 1778 [T. V.] (sines and tangents).

Art. 18. *Logistic and Proportional Logarithms.*

What are now called fractions or ratios used to be styled *logistic* numbers; and logistic logarithms are logarithms of ratios: thus a table of $\log \frac{a}{x}$, x being the argument and a a constant, would be called a table of logistic or proportional logarithms; and since $\log \frac{a}{x} = \log a - \log x$, it is clear that the tabular results only differ from those of an ordinary table of logarithms by the subtraction of a constant and a change of sign. It appears that KEPLER, in his 'Chilias' described below, originated tables of this kind; but the step that separates logistic from common logarithms is so small that no great interest attaches to their first appearance. The use of the tabulation of $\log \frac{a}{x}$ in the working of proportions in which the third term is a fixed quantity a is evident.

There seems a tendency to keep the name *logistic logarithms* for those tables in which $a = 3600'' = 1°$ (so that the table gives $\log 3600 - \log x$, x being expressed in minutes and seconds), and to use the name *proportional logarithms* when a has any other value. We have not met with any modern table of this kind forming a separate work; and such tables are usually of no great extent. They are to be found, however, in many collections of tables; and the logistic logarithms from CALLET were published separately at Nuremberg in a tract of 9 pp. in 1843 (see title in § 5).

It may be remarked that tables of $\log \frac{a}{x}$ often extend to values of x greater than a; and then, in the portion of the table for which this is the case, the mantissæ are rendered positive (by the supposed addition of the characteristic -1, which is omitted) before tabulation.

Kepler, 1624. We cannot do better than follow De Morgan's example, and give a specimen of the table, which contains five columns:—

53· 36·36	80500·00	19· 19·12	21691·30	48·18
5·48			124·15	

The *sinus* or *numerus absolutus* is 805, which (to a radius 1000) is the sine of 53° 36′ 36″, and the *Napierian* logarithm is 2169130. The third and fifth columns are explained as follows:—if 1000 represent 24^h, then 805 represents $19^h\,19^m\,12^s$; and if 1000 represents 60°, then 805 represents 48° 18′; there are interscript differences for the first and fourth columns. Thus, as De Morgan remarks, Kepler originated *logistic logarithms*. Kepler's tract is reprinted by Maseres in vol. i. of his 'Scriptores Logarithmici' (1791); and there is also reprinted there "Joannis Kepleri....supplementum chiliadis logarithmorum....Marpurgi, 1625," the original of which we have not seen, but it contains no table. The copy of the 1624 work we have described is in the Cambridge University Library. For an account of Kepler's 'Tabulæ Rudolphinæ,' see De Morgan.

Proportional logarithms for every second, a being 3°, are given almost invariably in collections of nautical tables, usually to four places, but sometimes to five. T. 74 of RAPER, so frequently referred to in § 4, is a four-place table of this kind, and was, as we have seen stated in several places, first computed by Maskelyne. The reference was made to Raper rather than to any other of the numerous places where it occurs, as his work on Navigation is one of the best-known, and has been through numerous editions. Prof. Everett (Phil. Mag. Nov. 1866) says, quoting Raper, that proportional logarithms as at present used are a source of perpetual mistakes even to expert computers; but this must be intended to apply rather to practical men, as for the mathematical calculator they are very convenient.

The following is a list of tables on the subject of this article, which are described more fully in § 4.

Logistic logarithms for every second to 1°, viz. $\log 3600 - \log x$.—(To 4 places) GARDINER, 1742 and (Avignon) 1770, T. III. (to 4800″); DODSON, 1747, T. XXXVI. (to 4800″); SCHULZE, 1778 [T. IV.] (to 3600″); VEGA, 1797, Vol. II. T. IV. (to 3600″); GORDON, 1849, T. XXI. (to 3600″); CALLET, 1853 [T. XI.] (to 5280″); HUTTON, 1858, T. VII. (to 5280″); INMAN, 1871 [T. I.] (to 3600″, intervals of 2″).

Proportional logarithms for every second to 3°, viz. $\log 10{,}800 - \log x$.—(To 5 places) RIOS, 1809, T. XIV.; LAX, 1821, T. XIV.; GALBRAITH,

1827, T. X.; BAGAY, 1829, T. XXII.; COLEMAN, 1846, T. XXIV.; INMAN, 1871 [T. II.]

(To 4 places) (viz. T. 74 of RAPER) CROSWELL, 1791, T. V.; MASKELYNE (Requisite Tables), 1802, T. XV.; BOWDITCH, 1802, T. XV.; ANDREW, 1805, T. XIV.; MACKAY, 1810, T. LI.; MOORE, 1814, T. XXV.; DUCOM, 1820, T. VII.; KERIGAN, 1821, T. XII.; STANSBURY, 1822 [T. II.]; RIDDLE, 1824, T. XXIX.; J. TAYLOR, 1833, T. XXXVI.; BEVERLEY (1833?), T. XVIII.; NORIE, 1836, T. XXXIV.; GREGORY &c., 1843, T. VIII.; GRIFFIN, 1843, T. 41; J. TAYLOR, 1843, T. 35; RÜMKER, 1844, T. XXIV.; GORDON, 1849, T. X.; DOMKE, 1852, T. XL.; THOMSON, 1852, T. XIX.; RAPER, 1857, T. 74.

Proportional logarithms for every minute to 24^h, viz. $\log 1440 - \log x$.—(To 5 places) GALBRAITH, 1827, T. IX.

(To 4 places) STANSBURY, 1822, T. *G*; LYNN, 1827, T. *E*; GREGORY &c. 1843, T. XII.; GORDON, 1849, T. XIX.; THOMSON, 1852, T. X.; RAPER, 1857, T. 21A.

Art. 19. *Tables of Gaussian Logarithms.*

Gaussian logarithms have for their object to facilitate the finding of the logarithms of the sum and difference of two numbers whose logarithms are known, the numbers being themselves unknown; on this account they are often called *Addition and Subtraction logarithms.* The problem is therefore; given $\log a$ and $\log b$, find $\log (a \pm b)$ by the taking out of only one logarithm. The utility of such logarithms was first pointed out by Leonelli, in a very scarce book printed at Bordeaux in the year XI. (1802 or 1803), under the title "Supplément logarithmique;" but it met with no success. Leonelli's idea was to construct a table to 14 places—an extravagant extent, as Gauss has remarked. The first table constructed was calculated by Gauss, and published by him in vol. xxvi. (p. 498 *et seq.*) of Zach's 'Monatliche Correspondenz' (1812): it gives B and C for argument A, where $A = \log x$, $B = \log\left(1 + \frac{1}{x}\right)$ $C = \log(1 + x)$, so that $C = A + B$; and the use is as follows. We have identically—

$$\log(a + b) = \log a + \log\left(1 + \frac{b}{a}\right)$$
$$= \log a + B \quad \left(\text{for argument } \log \frac{a}{b}\right).$$

The rule therefore is, to take $\log a$, the larger of the two logarithms, and to enter the table with $\log a - \log b$ as argument, we then have $\log(a + b) = \log a + B$, or, if we please, $= \log b + C$. For the difference, the formula is $\log(a - b) = \log b + A$ (argument sought in column C) if $\log a - \log b$ is greater than ·30103, and $= \log b - A$ (argument sought in column B) if $\log a - \log b$ is less than ·30103; there are also other forms. Gauss remarks that a complete seven-figure table of this kind would be very useful. Such a table was formed by MATTHIESSEN; but the arrangement is such that very little is gained by the use of it. This Gauss has pointed out in No. 474 of the 'Astronomische Nachrichten,' 1843, and in a letter (1846) to Schumacher, quoted by De Morgan. Gauss's papers on logarithms and reviews of logarithmic tables from the 'Göttingische gelehrte Anzeigen,' 'Astronomische Nachrichten,' &c., are reprinted together on pp. 241–264 of t. iii. of his 'Werke,' 1866. Of these pp. 244–252 have reference to Gaussian logarithms and contain reviews of PASQUICH, 1817 (§ 4), and MATTHIESSEN,

1818 (below). The largest tables are ZECH (reprinted from HÜLSSE's edition of VEGA) and WITTSTEIN, which answers the purpose Gauss had in view the best of all: there is also a good introduction to the latter (in French and German), explaining the use and objects of the tables.

Whenever in this Report the letters A, B, C are used in the description of Gaussian logarithms, they are always supposed to have the meanings assigned to them by Gauss (which are explained above), unless the contrary is expressly stated. Of course all Gaussian tables have reference to Briggian (not hyperbolic) logarithms.

Leonelli, 1806. This is the German translation of Leonelli's work, and suggested to Gauss the construction of his table in Zach's 'Correspondenz.' The book consists of two parts: in the first there are 9 pages of tables &c. wanted in the construction of logarithms, viz. log x, log $1{\cdot}x$, log $(1{\cdot}0x)$,.... log $(1{\cdot}0000000000x)$, for $x = 1, 2, \ldots 9$, to 20 places, and the same for hyperbolic logarithms; also log ·1, ·2....(9·9), and log $1{\cdot}0x$, log $1{\cdot}000x$, log $1{\cdot}00000x$, and log $1{\cdot}0000000x$, for $x = 01, 02, \ldots 99$.

The second part is headed "Theorie der Ergänzungs- und Verminderungs-Logarithmen zur Berechnung der Logarithmen der Summen und Differenzen von Zahlen aus ihren Logarithmen," and on pp. 52–54 the specimen table is given; log x being the argument, it gives log $\left(1 + \frac{1}{x}\right)$ and log $(1 + x)$ as tabular results to 14 places, for arguments from ·00000 to ·00104 at intervals of ·00001. [It will be noticed that the above are the same as Gauss's A, B, and C.] The middle page of this table (p. 53) is nearly an inch longer than any of the other pages of the book. The original work, according to HOÜEL, 1858, 'Avertissement,' p. vi, was published at Bordeaux, An XI., under the title "Supplément logarithmique," &c.

Gauss, 1812. $B\left(= \log\left(1 + \frac{1}{x}\right)\right)$, and $C\,(= \log(1 + x))$ are given for argument $A\,(= \log x)$ from A = ·000 to 2·000 at intervals of ·001, thence to 3·40 at intervals of ·01, and to 5·0 at intervals of ·1, all to 5 places, with differences. The table occupies 27 small octavo pages. Gauss's paper is reprinted from the 'Correspondenz' in t. iii. pp. 244–246 of his 'Werke,' 1866; but the table is not reproduced there.

Matthiessen, 1818. B and C are given to 7 places for argument A, from A = ·0000 to 2·0000 at intervals of ·0001, thence to 3·000 at intervals of ·001, to 4·00 at intervals of ·01 and to 5·0 at intervals of ·1; also for A = 6 and 7, with proportional parts.

As C = A + B, the last three figures are the same for B and C, so that the arrangement is, column of A, column of first four figures of B, column of first four figures of C, column of last three figures of B and C, proportional parts; the eye has therefore to look in two different columns to take out a logarithm. There is also another disadvantage, viz. that as there are only four figures of argument, if it is to be used as a seven-figure table *three* more must be interpolated for.

The introduction is both in German and Latin.

Mr. Gray, who recalculated a considerable portion of this table, found that it contained numerous errors (see GRAY, 1849, below). See also the introductory remarks to this article.

Weidenbach, 1829. Modified Gaussian logarithms. Log x (= A) is the argument, and log $\frac{x+1}{x-1}$ (= B) is the tabular result. A and B are thus

"reciprocal," the relation between them being, in fact, $10^{A+B} = 10^A + 10^B + 1$, so that either A or B may be regarded as the argument. The table gives B to five places with differences, from A = ·382 to A = 2·002 at intervals of ·001, from A = 2·00 to A = 3·60 at intervals of ·01, and then to 5·5 at intervals of ·1. The commencement of the table being at A = ·382 does not render it incomplete, by reason of the reciprocity referred to above, since for arguments less than ·382 we can take B as the argument. Thus, at the beginning of the table A and B are very nearly equal, viz. A = ·382, B = 0·38355; A = ·383, B = ·38255. There is an introduction of 2 pp. by Gauss.

The use of the table in the solution of triangles is very apparent, *e.g.* in the formula $\cot \frac{C}{2} = \frac{a+b}{a-b} \tan \frac{A-B}{2}$, in Napier's analogies, &c.

Gray, 1849. Modified Gaussian logarithms. T. I. Log $(1+x)$ is the tabular result for log x as argument; and the range is from log x = ·0000 to 2·0000 at intervals of ·0001, to 6 places, with proportional parts to hundredths (viz. 100 proportional parts of each difference).

T. II. Log $(1-x)$ is the tabular result for log x as argument; and the range is from log $x = \bar{3}\cdot000$ to $\bar{1}\cdot000$ at intervals of ·001, and from $\bar{1}\cdot0000$ to $\bar{1}\cdot9000$ at intervals of ·0001, to 6 places, with complete proportional parts. The first table might have been copied from Matthiessen by contracting the 7 places of the latter to 6; but it was recalculated by Mr. Gray, and many errors were thereby found in Matthiessen's table (Introduction, p. vi); the second table was also the result of an original calculation. Some remarks and references on the subject of Gaussian logarithms &c. will be found in the Introduction to the work.

Since writing the above account, Mr. Gray has sent us a copy of his 'Addendum to Tables and Formulæ for the computation of Life Contingencies....Second Issue, comprising a large extension of the principal table....' London, 1870, 8vo (26 pp. of tables and an introduction), which is a continuation of the work under notice, and is intended to be bound up with it, a new title having reference to the whole work when so augmented being added. The 'Addendum' contains a table of log $(1+x)$ to 6 places for argument log x, from log $x = \bar{3}\cdot000$ to $\bar{1}\cdot000$ at intervals of ·001, and from $\bar{1}\cdot0000$ to 0·0500 at intervals of ·0001, the latter portion having proportional parts for every hundredth of the differences added: the whole of course the result of an original calculation. Mr. Peter Gray was the first to perceive the utility of Gaussian logarithms in the calculation of life contingencies, and to him is due their introduction as well as the calculation of the necessary tables, which it is evident are valuable mathematically, apart from the particular subject for which they were undertaken.

Zech, 1849. Table of seven-figure Gaussian logarithms. Denoting, as was done by Gauss, log x, log $\left(1+\frac{1}{x}\right)$, and log $(1+x)$, by A, B, C respectively, then the table gives B to seven places, from A = ·0000 to A = 2·0000 at intervals of ·0001, from A = 2·000 to A = 4·000 at intervals of ·001, and thence to 6·00 at intervals of ·01, with proportional parts throughout; the whole arranged as an ordinary seven-figure logarithm table, and headed *Addition* table.

The *Subtraction* table gives C to 7 places, from B = ·0000000 to ·0003000 at intervals of ·0000001, thence to ·050000 at intervals of ·000001, and thence to ·30300 at intervals of ·00001 to seven places, with proportional parts.

The addition table occupies 45 pp., the subtraction table 156 pp. The whole is a reprint from HÜLSSE'S VEGA of 1849, the paging being unaltered, and running from 636 to 836. The second edition is identical with the first, except that the 3 pp. of introduction are omitted.

Wittstein, 1866. A fine table of Gaussian logarithms in a modified form. B $(=\log(1+x))$ is given to seven places for the argument A $(=\log x)$ for values of the argument from 3·0 to 4·0 at intervals of ·1, from 4·00 to 6·00 at intervals of ·01, from 6·000 to 8·000 at intervals of ·001, from 8·0000 to 10·0000 at intervals of ·0001, and also from ·0000 to 4·0000 at the same intervals. Differences and proportional parts (or rather multiples) are given, except on one page (p. 5), where they are given for alternate differences as there is not sufficient space.

The arrangement is similar to that of a seven-figure logarithmic table. The figures have heads and tails, and are very clear.

On p. 127 there is given a recapitulation to three places, and to hundredths, of part of the table and the formulæ. A complete explanation is given in the introduction to the work.

Gaussian logarithms are very useful in the solution of triangles in such formulæ as $\cot\frac{C}{2}=\frac{a+b}{a-b}\tan(A-B)$, in which WEIDENBACH'S table would also be useful.

The following is a list of tables of Gaussian logarithms contained in works noticed in § 4.

Tables of Gaussian logarithms.—PASQUICH, 1817, T. III. (5 places); [ENCKE, 1828] [T. III.] (4 places); KÖHLER, 1832 [T. III.]; HÜLSSE'S VEGA, 1840, T. XII.; MULLER, 1844 [T. II.]; [SHEEPSHANKS, 1844] [T. V.]; KÖHLER, 1848 [T. II.]; SHORTREDE, 1849, T. VII.; FILIPOWSKI, 1849, T. II.; HOÜEL, 1858, T. III.; GALBRAITH and HAUGHTON, 1860 [T. IV.]; OPPOLZER, 1866.

Art. 20. *Tables to convert Briggian into Hyperbolic Logarithms, and vice versâ.*

Tables for the conversion of Briggian into hyperbolic logarithms, and *vice versâ*, are given in nearly all collections of logarithmic tables. Such a table merely consists of the first hundred (sometimes only the first ten) multiples of the modulus ·43429 44819 03251 82765 11289...., and its reciprocal 2·30258 50929 94045 68401 79914...., to five, six, eight, and ten or even more places. A list of such tables, contained in works described in § 4, is given below; tables of this kind, however, rarely exceed a page in extent, and are very easy to construct. It is not unlikely that the list is far from perfect, for in some cases it was not thought worth while noticing such tables when of small extent and to few places. We mention DEGEN (§ 4) as containing one of the largest.

The following is a list of tables contained in works noticed in § 4.

To convert Briggian into hyperbolic logarithms and vice versâ.—(To more than 10 places) SCHULZE, 1778 [T. I.]; DEGEN, 1824, T. II.; SHORTREDE, 1849, T. VII.; CALLET, 1853 [T. IV.]; PARKHURST, 1871, T. V.

(To 10 places) SCHRÖN, 1860, T. I.; BRUHNS, 1870.

(To 8 places) SHORTREDE (Tables), 1844, T. XXXIX.; KÖHLER, 1848, [T. I.]; HOÜEL, 1858, T. III.

(To 7 places) BREMIKER, 1852, T. I.; BREMIKER'S VEGA, 1857, T. I.; DUPUIS, 1868, T. V.

(To 6 places) DODSON, 1747, T. XXXVII.

(To 5 places) De Prasse, 1814 [T. II.] (?); Galbraith and Haughton, 1860 [T. I.]; Wackerbarth, 1867, T. V.

See also Trotter, 1841 [T. I.]; Schlömilch [1865?]; Rankine, 1866, T. 3; and Pineto, 1871 (§ 3, art. 13).

Art. 21. *Interpolation Tables.*

All the tables of proportional parts (described in § 3, art. 2) are interpolation tables in one, and that the most usual, sense; and similarly, multiplication and product tables may be so regarded (see § 3, art. 2). We may, however, especially refer to Schrön, 1860, as its printed title describes it as an interpolation table—a designation not common. The only separate table we have seen for facilitating interpolations, when the second, third, &c. differences are included, is Woolhouse, noticed below. We may also refer to Godward's tables (title in § 5), but they seem of such special application that we have not thought it necessary to describe their contents.

Woolhouse, 1865. Papers extracted from vols. xi. and xii. of the 'Assurance Magazine.' There are 9 pp. of interpolation tables (viz. pp. 14–22). The work contains a clear explanation of methods of interpolation, with developments.

The following are references to tables described in § 4.

Binomial-theorem coefficients.—Schulze, 1778 [T. XIII.]; Vega, 1797, Vol. II. [T. VI.]; Barlow, 1814, T. VII.; Hantschl, 1827, T. IX.; Hülsse's Vega, 1840, T. XIII.; Köhler, 1848, T. X.; Parkhurst, 1871, T. XXXII. See also Rouse (§ 3, art. 25).

Other interpolation coefficients.—Peters, 1871 [T. IV.], I. and II.

Coefficients of series terms.—Vega, 1797, Vol. II. [T. VI.]; Lambert, 1798, T. XLIV.; Hulsse's Vega, 1840, T. VIII.; Köhler, 1848, T. XI.

Art. 22. *Mensuration Tables.*

We have made no special search for tables on mensuration (such as areas of circles of given radius, volumes of cones of given base and altitude, &c.), and have only included those that have fallen in our way in the course of seeking for more strictly mathematical tables during the preparation of this Report. As, however, for several reasons it seems desirable that a complete list of such tables should be formed, we shall endeavour to render this Article as nearly perfect as we can in the supplement. One reason, however, why such tables are not of very high mathematical value is that the measures are generally expressed in more or less arbitrary units, such as yards, feet, inches, &c., or metres &c.

We may especially refer to the large table of circular segments in Sharp, 1717 (§ 4).

Sir Jonas Moore (1660?). The table is a very small one, and scarcely occupies a third of a folio page. It gives the periphery of an ellipse for one axis as argument (the other axis being supposed equal to unity) to 4 places, with differences; the range of the argument is from ·00 to 1·00 at intervals of ·01. Thus, to find the perimeter of an ellipse, axes 1 and ·78, we enter the table at 78 and find 2·8038. If one axis is not equal to unity, a simple proportion of course gives the perimeter. After working out four examples, the author proceeds: "I have made above 45,000 arithmetical operations for this table, and am now well pleased it is finished.

Some perhaps may find shorter ways, as I believed I had myself, till advised otherwise by the truly Honourable the Lord Bruncker, &c." This is perhaps the first tabulation of an elliptic integral.

Bonnycastle, 1831. A table of the areas of segments (pp. 295–300): the same as T. XIII. of HANTSCHL.

Todd, 1853. T. I. Areas (to 6 places) and circumferences (to 5 places) of circles for the diameter as argument, the range being from diameter $\frac{1}{16}$ to diameter 24 at intervals of $\frac{1}{16}$; the decimal fractions (to 4 places) equivalent to $\frac{1}{16}$, $\frac{2}{16}$, &c., are printed at the top of each page.

T. II. The same from diameter 24 to 100 at intervals of $\frac{1}{8}$ (4 places only for the circumferences).

T. III. The same from diameter 12 to 600 at intervals of unity. Both areas and circumferences are only given to 4 places.

T. IV. The same from diameter ·1 to 100 at intervals of ·1. Areas to 6 places, circumferences to 5.

T. V. to VII. stand in exactly the same relation to spheres that T. I. to IV. do to circles, except that T. V. is equivalent to T. I. and II., the intervals being $\frac{1}{8}$ from 1 to 100; and T. VI. commences at 1 (not 12). The volumes and superficies are given to 4 places.

T. VIII. Areas (exact) and diagonals (to 5 places) of squares for side as argument, from $\frac{1}{8}$ to 100 at intervals of $\frac{1}{8}$.

In all cases the arguments are given in inches, and the results in square and cubic inches; but in T. III. and VI. the corresponding numbers of linear, square, and cubic feet are also given.

The original work, of which this is the second and greatly augmented edition, was published in 1826; and the tables were the result of original calculations. There are besides some specific gravities, &c.

The following tables are more fully described in § 4.

Mensuration tables.—SHARP, 1717 [T. II.], areas of segments of circles; [T. III.], table for computing the solidity of the upright hyperbolic section of a cone; DODSON, 1747, T. XXVI., XXVIII., and XXIX.; GALBRAITH, 1827, T. XV. and XVI. (Introd.); HANTSCHL, 1827, T. XIII.; TROTTER, 1841 [T. V.] and [T. XII.]; WILLICH, 1853, T. *C* (circumferences and areas of circles); BEARDMORE, 1862, T. 34 (circumferences and areas of circles); RANKINE, 1866, T. 4 and 5.

Art. 23. *Dual Logarithms.*

Dual logarithms were invented, and the tables of them calculated, by Mr. Oliver Byrne, who, besides the work described below, has published 'Dual Arithmetic' and the 'Young Dual Arithmetician' on the subject. A dual number of the ascending scale is a continued product of powers of 1·1, 1·01, 1·001, &c., taken in order, the powers only being expressed. To distinguish these numbers from ordinary numbers, they are preceded by the sign $\diagdown\!|\!\diagup$: thus, $\diagdown\!|\!\diagup\ 6, 9, 7, 6 = (1{\cdot}1)^6 (1{\cdot}01)^9 (1{\cdot}001)^7 (1{\cdot}0001)^6$; $\diagdown\!|\!\diagup\ 0, 0, 2 = (1{\cdot}1)^0 (1{\cdot}01)^0 (1{\cdot}001)^2$, the numbers following the $\diagdown\!|\!\diagup$ being called dual digits. When all but the last digit of a dual number are zeros, the dual number is called a dual logarithm; but the dual logarithms used by Mr. Byrne are "of the eighth position," viz. there are 7 ciphers between the $\diagdown\!|\!\diagup$ and the logarithm.

A dual number of the descending branch is a continued product of powers of ·9, ·99, ·999, &c., and the dual number is followed by the symbol $\diagup\!|\!\diagdown$: thus, $({\cdot}9)^3 ({\cdot}99)^2 =$ '3 '2 $\diagup\!|\!\diagdown$; $({\cdot}999)^3 ({\cdot}999999)^2 =$ '0' 0' 3' 0' 0' 2 $\diagup\!|\!\diagdown$. In the descending branch also a dual number reduced to the eighth position is

called a dual logarithm, and is to be considered negative if the ascending dual logarithm is taken positive, and *vice versâ*.

Byrne, 1867. T. I. contains all the dual numbers of the ascending branch of dual arithmetic from \|/ 0, 0, 0, 1 to \|/ 7, 3, 1, 9, and their corresponding dual numbers and natural numbers. The range of the dual logarithms is from 00000 to 69892175, and of the natural numbers from 1·00000000 to 2·01167234. Marginal tables are added, by means of which all dual numbers of 8 digits, and their corresponding dual logarithms and natural numbers, may be derived: the table occupies 74 pp.

T. II. Dual logarithms and dual numbers of the descending branch of dual arithmetic from '0 '0 '0 '1 '0 '0 '0 '0 /|\ to '3 '6 '9 '9 '0 '0 '0 '0 /|\, with corresponding natural numbers. The range of the dual logarithms is from '10001 to '39633845, and of the natural numbers from ·99990000 to ·67277805. Marginal tables are added, by means of which all intermediate dual numbers of 8 digits and their corresponding dual logarithms and natural numbers may be derived. This table is printed in red, T. I. and III. being in black. It occupies 38 pp.

T. III. Natural sines and arcs to 7 places for every minute of the quadrant. The length of the arc is, of course, the circular measure of the angle, so that we have a table of circular measures to minutes: the arrangement is quadrantal. Proportional parts are given for 10″, 20″....90″ for each difference; and these occupy two thirds of the page. There are small proportional-part tables for the arc: the table occupies 90 pp.

The author claims that his tables are incomparably superior to those of common logarithms, and asserts that "these tables are equal in power to Babbage's and Callet's, and take up less than one eighth of the space" ('Dual Arithmetic,' part ii. p. ix). *Babbage and Callet* seems an error (unless the CALLET of 1827 (§ 3, art. 15) is meant), as the latter work contains the table of the logarithms of numbers which is the sole contents of the former. Mr. Byrne's works on the subject are:—'Dual Arithmetic: a new Art,' London, 1863, 8vo (pp. 244); 'Dual Arithmetic: a new Art. New Issue, with a complete analysis,' 1864 (pp. 83) [this work contains a table of 3 pp., "to facilitate the conversion of dual numbers into common ones, or the converse"]; 'Dual Arithmetic: a new Art. Part the Second' (pp. 218), and the work above described. Mr. Byrne has also published 'The Dual Doctrine of Angular Magnitude and Functions, &c.,' and the 'Young Dual Arithmetician,' neither of which we have seen: the latter contains an abridgment to 3 dual digits of the tables in the work described above.

In spite of the somewhat extravagant claims advanced by the author for his system, dual logarithms have found but little favour as yet either from mathematicians or computers.

Art. 24. *Mathematical Constants.*

In nearly all tables of logarithms there is a page devoted to certain frequently used constants and their logarithms, such as π, $\frac{1}{\pi}$, π^2, $\sqrt{\pi}$, $\sqrt[3]{\frac{\pi}{6}}$, &c., the radius of the circle in degrees, minutes, &c., the modulus &c. There are not generally more than four or five logarithms involving π given; and usually half the page is devoted to constants relating to the conversion of weights and measures. It is only necessary, therefore, here to refer to works in which there is a better collection than usual of constants.

A very good collection is given by MAYNARD (described below), and also by BYRNE, 1849. This portion of the present Report is very far from complete, as the values of mathematical constants have, as a rule, appeared in periodical publications, while those only that are most used by the general computer are to be found in collections of mathematical tables. We refrain, therefore, from giving references to several periodicals we have met with containing constants, as they belong properly to a subsequent portion of the Report; and it is hoped that, after the completion of the examination of the memoirs, a pretty complete list, either of the constants themselves, or at all events of the places where they are to be found, will be given.

We may, however, notice a paper of Paucker's in the first volume of 'Grunert's Archiv der Mathematik und Physik,' in which a number of constants involving π are given to a great many places, and Gauss's memoirs on the lemniscate-functions ('Werke,' t. iii. pp. 426 &c.), where $e^{-\pi}$, $e^{-\frac{1}{4}\pi}$, $e^{-\frac{3}{4}\pi}$, &c. are calculated to about fifty places. On Euler's constant, see 'Proceedings of the Royal Society,' t. xv. p. 429; t. xvi. pp. 154, 299; t. xviii. p. 49 (Shanks); t. xix. p. 514 (Glaisher); t. xx. pp. 27, 29 (Shanks). On e, the base of the Napierian logarithms, $\log_e 2$, $\log_e 3$ &c., see, besides the places just referred to, 'Roy. Soc. Proc.' t. vi. p. 397, and 'Brit. Assoc. Report' (Sections) 1871, p. 16, and also SHANKS 1853 (§ 4). Several constants are to be found in the different works of Maseres. Mr. Maynard and Mr. Merrifield have independently calculated $\log_e M$ and $\log_e m$ (M and m being the modulus and its reciprocal) to 30 places ('Assurance Magazine,' t. vi. p. 298).

The value of π has been calculated to 500 places of decimals by Shanks and Richter independently, and to 707 places by the former alone: see references, 'Messenger of Mathematics,' December 1872 and July 1873. Mr. Shanks's latest value appears in the 'Roy. Soc. Proc.' t. xxi. p. 319. It is proper here to remark that Rutherford's 208-decimal value of π, given in the 'Phil. Trans.' 1841, p. 283, is erroneous after the 152nd place: this value is reproduced in BYRNE, 1849 (§ 4), and in MAYNARD; so that it is erroneous also in both of these works.

[**Maynard.**] A good table of constants involving π, such as $\pi\sqrt{2}$, π^{-2}, $\sqrt{\pi}$, &c., and some few involving e &c., to a great many (generally 30) places. There are also other constants not included in the subjects of this Report.

The copy of these constants that we examined consisted of six leaves without a cover, and which were evidently extracted from some work. Mr. C. W. Merrifield, F.R.S., subsequently called our attention to the particularly good collection of constants in 'The Millwright and Engineers' Pocket Companion;.... By William Templeton.... Corrected by Samuel Maynard.... Fifteenth edition, carefully revised,' London, 1871, 8vo, and lent us a copy; and on examination it appeared that it was to this work that Maynard's collection belonged, where it occupies pp. 169–180. There are, altogether, 58 constants involving π, and their logarithms, given generally to 30 places, and 13 others that may also be properly styled mathematical. It is mentioned that part of the table had previously appeared in Keith's 'Measurer' (twenty-fourth edition, 1846). Templeton's work contains several other tables (areas of circles, &c.), and square roots which would have been included in this Report had we seen the book earlier; as it is they will be noticed in the Supplement. On Rutherford's value of π, quoted by Maynard, see introductory remarks to this article.

The following is a list of references to § 4.

Lists of Constants.—Dodson, 1747, T. XXVII.; Galbraith, 1827, T. LXIII.; Hantschl, 1827, T. XI.; [De Morgan], 1839 [T. V.]; Farley, 1840 [T. III.]; Müller, 1844 [T. IV.]; Shortrede (Tables), 1844, T. II.; Müller, 1844 [T. IV.]; Raper, 1846, T. V.; Köhler, 1848 [T. III.]; Byrne, 1849 [T. III.]; Bremiker, 1852, T. II.; Willich, 1853, T. XX., &c.; Shanks, 1853 (constants to a great many places); Bremiker's Vega, 1857; Hoüel, 1858, T. VIII.; Hutton, 1858, T. XII.; Galbraith and Haughton, 1860 [T. IV.]; Wackerbarth, 1867, T. IV., V., and XXI.; Bruhns, 1870.

Note.—Binomial-theorem coefficients and coefficients of series-terms are noticed under Interpolation Tables in § 3, art. 21.

Art. 25. *Miscellaneous Tables, figurate Numbers, &c.*

We have placed in this article tables which could not properly be described under any one of the previous twenty-four heads. The list is not, however, a long one, as we have frequently placed doubtful tables in the article which most nearly applied to them.

We may refer especially to Joncourt's table of triangular numbers (described below), which is perhaps unique. Reishammer's commercial logarithms and Montferrier's binary logarithms are described in § 3, art. 13. Picarte's table to facilitate the performance of divisions is described in § 3, art. 7. We may also particularly notice Degen's large table (§ 4) of log $1 \cdot 2 \ldots . x$). There is a table of binomial-theorem coefficients in Rouse (see below); and other tables of the same kind are referred to under *Interpolation Tables* in § 3, art. 21. Tables of endings of squares are noticed in § 3, art. 4; and tables for the solution of cubic equations, viz. $\pm (x - x^3)$, in § 3, art. 5.

Browne, 1731. Pp. 6 and 7 are occupied by a table headed "Area of the circle in degrees and to the 10,000th part of a degree." Calling $\frac{\pi}{360}$, a, it gives $a, 2a, 3a \ldots . 100a, 200a, 300a$, and $360a$ to 7 figures. There are also three other columns in which the results only differ by a change of decimal point.

Through a mistake in the printing in the copy before us, all the odd pages are upside down.

Heilbronner, 1742. On pp. 922–924, the numbers from unity to 140, 72, and 100 are expressed in the scales whose radices are 3, 2, and 12 respectively.

Joncourt, 1762 [T. I.]. A table of triangular numbers up to that of 20,000, viz. $\frac{n(n+1)}{2}$ for all numbers from $n = 1$ to 20,000 (the table occupies 224 pp.).

[T. II.] Cubes of numbers from 1 to 600.

There are 36 pages of explanation &c., in which it is shown how [T. I.] may be used in the extraction of square roots, &c. De Morgan refers to this book as "De la Nature.... de Nombres trigonaux," 1762, so we suppose some copies with the introduction &c. in French were published. The Royal Society's copy has "Dec. 23, 1762," written in ink underneath the printed date. The book is handsomely printed.

The Babbage Catalogue also gives the same work with an English title. 'The Nature and Notable Use of the most simple trigonal numbers, with

two additional tables, &c., translated from the Latin of E. de Joncourt by the author's self.'

Phillips, 1829. This is not properly a table at all. Names and an abbreviated way of writing them are suggested for all numbers up to 9 followed by 4000 figures, the chief peculiarity of the system being that 1000 is called ten hundred, and 10,000 a thousand, and so on. The only explanation of the object of the table is contained in the curiously untrue remark that, by adopting the author's names, "we obtain a clearer view of calculations which are generally called inconceivable only because we have hitherto adopted no terms to express and limit them." On Sir R. Phillips, and the value of his works, see De Morgan's 'Budget of Paradoxes' (1872), pp. 143–145.

D. Galbraith, 1838. A piece contains 4, 5....56 squares, and the table is to show the number of dozens in any number of pieces up to 100, &c. It contains $\frac{xy}{12}$ for $x = 4, 5 \ldots 56$, and $y = 1, 2, 3 \ldots 100, 200,$ 300, 400, and 500, the value of x being constant over any one page: thus $x = 15$, $y = 65$, we have given 81·3 for $\frac{1}{12}(15 \times 65) = 81\frac{3}{12}$. The table was calculated to give the number of handkerchiefs in any number of pieces, &c.

De Morgan, 1843. DEGEN's table (§ 4) of log $(1, 2 \ldots x)$ is reprinted to six places by De Morgan at the end of his article on "Probabilities" in the 'Encyclopædia Metropolitana.' The last figure is not corrected: the table occupies pp. 486–490.

Rouse (no date). The tables, which are neither elaborate nor very numerous, are not of sufficient mathematical value to render it necessary to do more than give a general idea of their contents. In the body of the work are a number of small tables of this kind:—A and B (of equal skill) play 21 games; and the odds in favour of A's winning 1, 2....20, 21 are given as tabular results. Similar tables are given for 20, 19....2 games played. Then we have the same when the odds in favour of A are 6 to 5, 5 to 4, 5 to 3, &c.,—the maximum number of games, however, being six. On a folding sheet at the end is given the number of ways in which 1, 2, 3....60 points can be thrown with 1, 2....10 dice, and also the number of ways in which 52 cards can be combined into 4 hands in any given manner (thus, 5 diamonds, 4 hearts, 3 spades, and 1 club can be obtained in 3421322190 ways); the factor and the result when the suits are not specified are also given. The mode of formation of the table is obvious.

On a folding sheet at the beginning of the book is given $(a + b)^n$ at full length for $n = 1, 2 \ldots 30$.

The following is a list of miscellaneous tables contained in works that are described in § 4. For greater convenience a brief description of the contents of each table is appended to the reference to it.

Figurate Numbers.—LAMBERT, 1798, T. XXXVII.

Hyperbolic Antilogarithms (viz. powers of e) and their Briggian logarithms.—SCHULZE, 1778 [T. I.]; VEGA, 1797, Vol. II. T. III.; LAMBERT, 1798, T. XI.; HÜLSSE's VEGA, T. VII.; KÖHLER, 1848, T. III.; SHORTREDE, 1844 [T. II.], III.; HUTTON, 1858, T. XII.; CALLET, 1853 [T. II.], III.

Miscellaneous.—SHARP, 1717 [T. I.] $\left(\text{multiples of } \frac{\pi}{4}\right)$; DODSON, 1747, T. XX. (combinations), T. XXIII. (permutations), T. XXXV. (seconds in any number of minutes less than 2°); SCHULZE, 1778 (Pythagorean triangles); MASERES, 1795 (multiples of primes); VEGA, 1797, Vol. II. [T. VII.] and [T. VIII.] (piling of shot); LAMBERT, 1798, T. II. (multiples of primes), T.

III. (products of consecutive primes), T. XVII. (numbers of the form $2^n 3^m 5^p 7^q$), T. XXIV. (ϕ, ϕ^2....for $\phi = 10{,}000''$ m, &c.), T. XXXII. (Functiones hyperbolicæ circularibus analogæ); BORDA and DELAMBRE, 1800 or 1801 [T. V.] (log sin $(x+2)$—log sin x, &c. centesimal); PEARSON, 1824 [T. II.] (1°, 2°....as decimals of the circumference); DEGEN, 1824, T. I. (large table of log $(1.2....x)$), T. III. (multiples of log 2, log 3, &c.); URSINUS, 1827 [T. IV.] (length of chords subtending given angles); HANTSCHL, 1827, T. XI. (multiples of constants); HARTIG, 1829 (contents of solids expressed in Fuss and Zoll); [DE MORGAN], 1839 [T. VI.], (log $(1.2.3....x)$); HÜLSSE'S VEGA, 1840, T. IV. (chord table), T. IX. F and G ($x\,\frac{1-x^n}{1-x}$, &c.); SHORTREDE (tables), 1849, T. IV. and V. (for calculating logarithms and antilogarithms), and T. VIII. (log $(1.2.3....x)$); DOMKE, 1852, T. XXX. $\left(\left\{x+\frac{y}{60}\right\}^2\right)$; SHANKS, 1853 [T. I.] (terms of $\tan^{-1}\frac{1}{5}$ and $\tan^{-1}\frac{1}{239}$); SCHRÖN, 1860, T. III. $\left(\text{hyp. log } 10^n \text{ and } 1+\frac{x}{10^n}\right)$; *SCHLÖMILCH [1865?] (elliptic quadrants); EVERETT, 1866; WACKERBARTH, 1867, T. II. (log $(1.2....x)$, log $(1.3....x)$, log $(2.4....x)$); PARKHURST, 1871, T. IV., VI.–VIII., X., XI., XV.–XVII., XIX., XXIV., XXIX., XXXVI. See also KULIK, 1848, T. 2–10 and 11 (Theory-of-number tables and multiples of π and $\frac{1}{\pi}$) (§ 3, art. 4).

§ 4. *Works containing Collections of Tables, arranged in alphabetical order.*

[The titles of the works can be found by reference to § 5.]

Académie de Prusse (1776). This collection of tables only contains two that come within the scope of this Report.

[T. I.] (vol. iii. pp. 172–207). Table of sines, expressed as arcs whose length is equal to that of the sine; viz. for x (expressed in degrees and minutes) as argument there is given the angle (expressed in degrees, minutes, seconds, and tenths of a second) whose circular measure is sin x, the argument x being given to every minute of the quadrant. There are no differences; and the arrangement of the table is quadrantal (not semiquadrantal). The table is due to Schulze.

[T. II.] (Vol. iii. pp. 258–271). Lengths of circular arcs, viz. the circular measures of 1°, 2°, 3°,....360°, of 1′, 2′,....60′, and of 1″, 2″,....60″ to 27 places. This table is by Schulze, in whose collection it also appears: see SCHULZE [T. VII.].

Both these tables are included under the head "Tables auxiliaires" in the third volume.

The whole work is attributed in the Royal Society's Catalogue to SCHULZE, and, from internal evidence we have little doubt, correctly.

Adams, 1796 [T. I.]. Six-figure logarithms to 10,860, written at length, with characteristics. Differences are added.

[T. II.] Log sines, tangents, and secants for every minute of the quadrant, to 6 places; with tables at the bottom of the page to facilitate interpolations.

[T. III.] Log sines, cosines, tangents, cotangents, secants, and cosecants for very quarter point, to 5 places.

Andrew, 1805. T. XIII. Squares of natural semichords, viz. $\sin^2 \frac{x}{2}$ from $x=0°$ to $x=120°$, at intervals of $10''$, to seven places, with differences and proportional parts for seconds. This valuable table occupies pp. 29–148 of the work.

T. XIV. Proportional logarithms to 3°, at intervals of a second, to four places; same as T. 74 of Raper.

The other tables are nautical.

Anonymous [1860?]. Four-figure logarithms of numbers from 100 to 1000, with proportional parts, on a card (about 12 in. by 10 in.). On the back, numbers (to four figures) to logarithms from ·000 to 1·000, at intervals of ·001, with proportional parts. Printed by J. Sittenfeld, published by Veit and Co., Berlin. No date. The Brit.-Mus. copy received April 2, 1860.

Bagay, 1829. T. XXII. Proportional or logistic logarithms for every second to 3° (or 3^h) to five places; same as T. 74 of Raper, except to five instead of four places.

T. XXIII. Seven-figure logarithms, from unity to 21,600 (with the corresponding degrees, minutes, and seconds), to seven places, with differences, but not proportional parts.

T. XXIV. Logarithms of sexagesimal numbers, viz. logarithms of numbers of seconds in all angles from 6° 10′ 0″ to 12°, at intervals of 1″, to five places.

Appendix.—Table of log sines and tangents for every second of the quadrant to seven places (without differences). The change in the middle of the column is beautifully clearly marked by a large black nucleus, surrounded by a circle, printed instead of zero. Only the first logarithm affected is so denoted; but the mark is so striking that it readily attracts the eye. The table was formed by interpolation from Callet, corrected by Taylor (see p. ii of the 'Avertissement'); 76 errors were thus found in Taylor. Some errata are given at the end of the work.

All the other tables are astronomical. This work, which has now become rare, is much esteemed.

Barlow, 1814. T. I. Squares, cubes, square and cube roots (to 7 places), reciprocals (to 9 places as far as 1000, afterwards to 10), and all factors of numbers from 1 to 10,000. Thus, for the factors of 4932 we have given $2^2 . 3^2 . 137$.

T. II. The first ten powers of numbers from 1 to 100. This table was taken from Hutton [T. IV.] and Vega (Tabulæ), vol. ii. T. IV. The errors given in this Report in Hutton are not reproduced in this table.

T. III. Fourth and fifth powers of numbers from 100 to 1000.

T. IV. *For the solution of the irreducible case in cubic equations*; viz. y^3-y is tabulated from $y=1{\cdot}0000$ to $1{\cdot}1549$, at intervals of ·0001, to 8 places.

T. V. Prime numbers from 1 to 100,103 (this table is incorrectly described on the titlepage to it as extending to 10,000 only).

T. VI. Hyperbolic logarithms, to 8 places, of numbers from unity to 10,000 (this table is incorrectly described on the titlepage to it as only extending from 1000 to 10,000).

T. VII. *Differential coefficients*, viz. the first six binomial-theorem coefficients, $\frac{n(n-1)}{1.2} \ldots \frac{n(n-1)\ldots(n-5)}{1.2\ldots6}$, from $n={\cdot}01$ to $1{\cdot}00$, at intervals of ·01, to 7 places.

These tables occupy 256 pp., and are followed by 78 pp. of formulæ, weights, and measures, &c.

There is a full introduction, stating whence the tables were derived, or, if computed, from what formulæ, &c. The hyperbolic logarithms were taken from WOLFRAM's table in SCHULZE; and the reciprocals, factors, square and cube roots, and several other tables were the result of independent calculations.

The squares, cubes, square and cube roots, and reciprocals from this table were reprinted and stereotyped, at the suggestion of De Morgan, in 1840 (see BARLOW's tables, 1840, in § 3, art. 4). The reprint thus gives T. I., the column of factors being omitted. A list of 90 errors in T. I. of the original work is given in the reprint; and 25 errors in T. VI. are given by Prof. Wackerbarth in the 'Monthly Notices of the Royal Astronomical Society' for April 1867.

Bates, 1781. [T. I.] Five-figure logarithms to 10,000, without differences.

[T. II.] Log sines and tangents (to 5 places), and natural sines and tangents (to 7 places), for every minute of the quadrant, semiquadrantally arranged: no differences.

The tables (which have a separate titlepage, bearing the date 1779) are preceded by 211 pp. of trigonometry, and followed by an Appendix on the motion of projectiles in a non-resisting medium. The work was intended for use in the Military Academy, Belmont, near Dublin.

Beardmore, 1862. Only 23 pages (pp. 84–106) of this work contain tables that come within the scope of this Report.

T. 34. Areas and circumferences of circles, to 3 places, for diameters ·1, ·2, ... ·9, and from 1·00 to 100, at intervals of ·25.

T. 35. Squares, cubes, fifth powers, square and cube roots (to 3 places), and reciprocals (to 9 places) for numbers from 1 to 100, the squares and square and cube roots being given as far as 1100.

T. 36. Six-figure logarithms of numbers from 100 to 1000.

T. 37. Log sines from 0° to 45° 50′, at intervals of 10′, to 6 places.

T. 38. Natural sines, tangents, and secants for 1°, 2°, ... 90°, to 6 places. The other tables relate to hydraulics, rainfall, &c.

The work was first published in 1850; and a second edition, in an extended form, was issued in 1851.

Beverley [1833?] T. VI. (p. 127). Any number of minutes less than 12^h expressed as a decimal of 12^h, to 4 places.

T. VI. (pp. 232–243). *Sexagesimal cosecants and cotangents* for every minute from 20° to 90°. A *sexagesimal* cotangent is the cotangent when the radius is taken = 60′ (or 1°); viz. it bears to 60′ the same ratio that the ordinary cotangent does to unity, and is usually expressed in minutes, seconds, and decimals of a second. The same, of course, holds for sines, cosines, &c. Thus the *sexagesimal* sine of 30° is 30′, cosecant 30° = 120′, &c.

In this table the quantities tabulated are not *sexagesimal* functions, but sexagesimal functions divided by 3 (and are therefore to radius 20′): we thus have cosec 30° = 40′. The table is given to two decimal places of a second.

T. XV. Sexagesimal sines, tangents, secants, and versed sines (viz. to rad. 60′) to every degree to 90°, to one decimal place of a second, with differences.

T. XVII. Log sines and tangents, from 18° to 90°, at intervals of 1′, to 4 places.

T. XVIII. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of RAPER.

Mr. Beverley made some improvements in TAYLOR's Sexagesimal Table (§ 3, art. 9), and devised a plan to introduce them into TAYLOR's table without reprinting it. He accordingly made application to the Board of Admiralty to be allowed to do so in the copies that remained unsold; but this was refused. He then offered to purchase all the unsold copies of HUTTON's 'Products' and TAYLOR's tables, in order to introduce his improvements; but his application was refused after the terms had been agreed upon, because he asked for six months' credit. In the Appendix he complains that "the immense labour that the calculation of his tables required him to exert had then ruined his constitution, and brought him to the verge of a premature grave." It is to be presumed that the Admiralty had some grounds for their refusal; but it is certain that no use has been made of Hutton or Taylor since the time of Mr. Beverley's application. No pains at any time seem to have been taken to circulate or make known any of the books published by the Board of Longitude, so that none of them have ever come into general use.

Mr. Beverley died in 1834, at the age of 39; and the present work was published after his death, as it contains a notice of his life by "J. B.", and evident traces of revision. He often refers to his Taylor's Sexagesimal Table, but no doubt it was never published. We have seen 'The Book of Formulæ &c., Cirencester, 1838,' by the same author; but it contains no tables.

Borda and Delambre, An IX. (1800 or 1801). [T. I.] Seven-figure logarithms of numbers from 10.000, to 100,000, with differences and proportional parts for all. The line is broken when a change takes place in the middle of it. It may be remarked that while in all modern tables of logarithms of numbers three figures are common to the block, and four only are given in the columns, in this table there are but two leading figures, and five are found in the columns, so that the lines are broken in very few instances. [T. II.] Eleven-figure logarithms of numbers to 1000, and from 100,000 to 102,000 (the latter with differences).

[T. III.] Log sines, cosines, tangents, and cotangents for centesimal arguments, viz. from 0' to 10', at intervals of 10'', and from 0^g to 50^g, at intervals of 10' to 11 places, without differences (^{g}, ', '' being used to denote centesimal degrees (or *grades* as they are sometimes called), minutes, and seconds).

[T. IV.] Hyperbolic logarithms of numbers from 1 to 1000 to 11 places.

[T. V.] Log differences of sines for every 1^g, 2^g, . . . 10^g throughout the quadrant, and the same for tangents for 1^g and 2^g, to 7 places, viz. log sin 2^g – log sin 1^g, log sin 3^g – log sin 2^g . . . . . throughout the quadrant of 100^g, log sin 4^g – log sin 2^g, log sin 6^g – log sin 4^g throughout the quadrant, &c. It is to be noticed, however, that in this mode of description of the table log sin 0^g must be treated throughout as 0 instead of $-\infty$; for facing 1^g we have given log sin 1^g (not log sin 1^g – log sin 0^g) in the first column; and facing 2^g in the second we have log sin 2^g &c.

[T. VI.] A great *centesimal* table, giving log sines, cosines, tangents, cotangents, secants, and cosecants from 0^g to 3^g, at intervals of 10'' (with full proportional parts for every second), thence to 50^g at intervals of 1', with full proportional parts for every 10'').

A page of tables for converting sexagesimals into centesimals &c., completes the work, which is a thick small-sized quarto, with clearly printed and not too heavy pages. After the printing of the work Prony asked Delambre to examine the TABLES DU CADASTRE (which are to every 10'' throughout the quadrant to 12 places; but see § 3, art. 13); and this gave Delambre the opportunity of reading them with Borda's table of sines and

tangents in this work: the result was the detection of a great number of last-place errors, which are given on pp. 117–119 (see p. 114, Préface de l'éditeur). There are other errata given on p. 116.

De Morgan remarks that Delambre is wrong in saying that HOBERT and IDELER's tables, 1799 (§ 4), subdivided the quadrant as minutely as those which he and Borda had published; but this is not the case, as the latter are as stated above. The mistake is one into which any one accustomed to describing tables would naturally fall, as the mode of arrangement gives the impression that the portion of [T. VI.] to 3^g is to every second, and that that from 3^g to 40^g is to every ten seconds: at first sight it is not easy to see why this was not the form of table adopted; but the reason for the arrangement being as it is was no doubt that the sine and cosecant, tangent and cotangent might be placed exactly on the same footing, as the proportional parts are the same for each pair. [Mr. Lewis, of Mount Vernon, Ohio, mentions that Bremiker has fallen into the same mistake as De Morgan did, thus giving additional proof of how misleading is the arrangement of the table to those who have not had occasion to use it: see 'Monthly Notices of the Royal Astronomical Society,' May 1873, vol. xxxiii. pp. 455–458.]

Bowditch, 1802. T. XII. For the conversion of arc into time.

T. XIII. Log $\frac{1}{2}$ elapsed time, mid time, and rising; same as T. XVI. of MASKELYNE, 1802. It is stated in the preface that this table was first published by Mr. Douwes, of Amsterdam, about 1740, and that he received £50 for it from the Commissioners of Longitude in England. 1024 (small) errors contained in this table in the second edition of REQUISITE TABLES are said to be here corrected.

T. XIV. Natural sines for every minute to 5 places.

T. XV. Proportional logarithms for every minute to 3°; same as T. 74 of RAPER.

T. XVI. Log sines, tangents, and secants for every quarter point to 5 places, and five-figure logarithms to 10,000.

T. XVII. Log sines, tangents, and secants for every minute of the quadrant to 5 places: arguments also in time (90°=*twelve* hours), and the complement to 12^h given also. The other tables are nautical.

On the titlepage it is stated that the tables are "corrected from many thousand errors of former publications;" most of them doubtless only affecting the last figure by a unit.

Bremiker, 1852. T. I. Six-figure logarithms to 1000, and from 10,000 to 100,010, with proportional parts; with degrees, minutes, and seconds corresponding to every tenth number of seconds, and ten times each such number; the change in the line is denoted by a bar over the 3rd figure in all the logarithms affected. The table is followed by the first hundred multiples of the modulus ·434 . . . and its reciprocal to 7 places.

T. II. Log sines (left-hand pages) and tangents (right-hand pages) for every second to 5° to 6 places, and log sines and tangents for every ten seconds of the quadrant to 6 places, with differences, and proportional parts beyond 5°. This is followed by small tables giving the circular measure of 1°, 2° . . . 180°, 1′, 2′, . . . , 60′, 1″, 2″. . . 60″ to 6 places; and for the conversion of arc into time &c. The last page contains a few constants.

There is an introduction of 82 pp., containing, among other things, an investigation "De erroribus, quibus computationes logarithmicæ afficiuntur."

Nine errors in this work are pointed out by Prof. Wackerbarth in the 'Monthly Notices of the Royal Astronomical Society" for April 1867.

Bremiker's Vega, 1857. T. I. Seven-figure logarithms to 1000, and

from 10,000 to 100,000, with differences and *all* the proportional parts on the page. The change of figure in the line is denoted by a bar placed over the fourth figures of all the logarithms affected. S and T (see § 3, art. 13) are given at the bottom of the page, as also are the numbers of degrees, minutes, and seconds corresponding to every tenth number in the number-column of the table. At the end of this table is a table containing the first hundred multiples of the modulus ·434 . . . and its reciprocal 2·302 . . . to 7 places.

T. II. Log sines and tangents from 0° to 5° to every second, to seven places: no differences. At the end of this table is given a page of circular arcs, containing the circular measure of 1°, 2°, . . . 180°; 1′, 2′, . . . 60′; 1″, 2″, . . . 60″ to seven places.

T. III. Log sines and tangents for every ten seconds of the quadrant, to seven places, with differences: proportional parts are added after 5°.

T. III. is followed by a page containing tables for the conversion of arc into time: the other tables are astronomical. On p. 547 are a few constants. The tables are stereotyped.

An edition with an English Introduction, edited by Prof. W. L. F. Fischer, was published in 1857 (title in § 5); the contents are the same as in the above work, the tables being printed from the same plates.

Bruhns, 1870. T. I. Seven-figure logarithms of numbers to 1000, and from 10,000 to 100,000, with differences, and *all* the proportional parts. The *all* is printed in italics, because in BABBAGE, CALLET, &c. only every other table of proportional parts near the beginning of the table is given, for want of space.

In this work there is no inconvenient crowding, as even where the side-tables are very numerous, the type, though small, is still very clear. The constants S and T, for the calculation of sines and tangents (§ 3, art. 13), are added, and placed at the bottom of the page, as also are the numbers of degrees, minutes, and seconds in every tenth number of the number-column (regarded as that number of seconds), and the same for each of these numbers multiplied by 10.

T. II. Log sines, cosines, tangents, and cotangents to every second from 0° to 6°, to seven places, with differences throughout, and *proportional parts*, except in the portion of the table from 10′ to 1° 20′, where the size of the page would not admit of their insertion.

T. III. Log sines, cosines, tangents, and cotangents from 6° to 45° to every ten seconds, to seven places, with differences and proportional parts. Of course room could not be found for the proportional parts of all the differences; but throughout all the table on no page are there less than six proportional-part tables.

On p. 186 the first hundred multiples of the modulus and its reciprocal are given, to ten places; and at the end of the book are tables of circular arcs, viz. the circular measure of 1°, 2°, . . . 180°, 1′, 2′, . . . 60′, 1″, 2″, . . . 60″, to ten places, a page for the conversion of arc into time, and some constants. In T. I. the change in the line is denoted by a bar placed over the fourth figure of all the logarithms affected, the similar change when the third figure is decreased being denoted in the other tables by an asterisk; a final 5 increased has a bar superscript. It is incorrectly stated in the preface that the practice of marking all the last figures that have been increased was introduced by SCHRÖN; for this innovation was due to BABBAGE (see his preface, p. x). Dr. Bruhns may, however, merely mean that the mark (viz. a bar subscript) introduced by SCHRÖN (1860) fatigues the eye and is of next to no use; and if so, we entirely agree with him. In BABBAGE the increase is

denoted by a point subscript, which the reader scarcely notices; but in Schrön the bar catches the eye at once and is confusing. The cases also in which it is necessary to know whether the last figure (unless a 5) has been increased are excessively rare; and in fact any one who wants such accuracy should use a ten-figure table.

On the whole, this is one of the most convenient and complete (considering the number of proportional-part tables) logarithmic tables for the general computer that we have met with; the figures have heads and tails; and the pages are light and clear. Further, we believe it is published at a low price.

Byrne, 1849 (Practical . . . method of calculating &c.). [T. I.] Primes to 5000, pp. xiii and xiv.

[T. II.] A very small table to convert degrees &c. into circular measure, p. xv.

[T. III.] List of constants (69 in number), chiefly relating to π (which Mr. Byrne denotes by p), such as 2π, 36π, $\frac{1}{12}\pi$, $\pi\sqrt{2}$, $\sqrt{\pi}$, &c. (pp. xviii to xxiii): the value of π is inaccurate; see § 3, art. 24.

[T. IV.] Logarithms of numbers from unity to 222, to 50 places (pp. 77–82).

Callet, 1853. [T. I.] Seven-figure logarithms to 1200, and from 10,200 to 108,000 (the last 8000 being to 8 places). Differences and proportional parts are added; but near the beginning of the table, where the differences change very rapidly, only the proportional parts of alternate differences are given, through want of room on the page (this is also done by Babbage and others). The constants S and T (see § 3, art. 13) for calculating the log sines and tangents of angles less than 3°, as also V the variation for 10″, are given in a line at the top of the page (see p. 113 of the Introduction). To the left of each number in the number-column are placed not only the degrees, minutes, &c. corresponding to that number of seconds, but also, in another column, those corresponding to ten times that number. When the change of figure occurs in the middle of the block of figures the line is broken —the best *theoretical* way of overcoming the difficulty. De Morgan and others, however, have expressed a strong dislike to it; and we agree with them.

[T. II.] I. Common and hyperbolic logarithms of numbers from 1 to 1200 to 20 places, the former being on the left and the latter on the right-hand pages. II. Common and hyperbolic logarithms of numbers from 101,000 to 101,179 to 20 places, with first, second, and third differences, the hyperbolic logarithms being on the right-hand pages. (Note. All the common logarithms from 101,143 to 101,179, with one exception, contain errors.) III. Common and hyperbolic antilogarithms from ·00001 to ·00179 at intervals of ·00001, and from ·000001 to ·000179 at intervals of ·000001, respectively, to 20 places, with first, second, and third differences.

[T. III.] I. Common logarithms (to 61 places) and hyperbolic logarithms (to 48 places) of all numbers to 100, and of primes from 100 to 1097; and (II.) from 999,980 to 1,000,021: the hyperbolic logarithms occupy the right-hand pages as before.

[T. IV.] The first hundred multiples to 24 places, and the first ten multiples to 70 places, of the modulus ·434 . . . and its reciprocal 2·302. . .

[T. V.] Ratios of the lengths of degree &c. (ancient and modern) to the radius as unit, viz. the circular measure of 1°, 2°, . . . 100°, 1′, 2′, . . . 60′, 1″, 2″, . . . 60″, and of the corresponding quantities in the centesimal division of the right angle (1^g . . . 100^g; 1` . . . 100`; 1`` . . .100``) to 25 places.

[T. VI.] Log sines and tangents for minutes (*centesimal*) throughout the quadrant (to seven places), viz. from 0^g to 50^g, at intervals of 1`, with differences.

The order of the columns is sine, tangent, difference for sine, difference for tangent, cosine; but this arrangement only holds up to 5^g, when differences are added for the cosine also. A change in the figure at the top of the column is denoted in the column by a line subscript under all the figures of the first logarithm affected, which arrests the eye at once.

[T. VII.] Natural and log sines (to 15 places) for every 10' (ten minutes centesimal) of the quadrant. It is as well here to note that in the log sine and cosine columns only nine figures are given, as the preceding figures are obtainable from [T. VI.]; two, however, are common to both: thus from [T. VI.] we find log sin 10'=7·1961197, and in [T. VII.] we have given, corresponding to log sin 10', 969843372; so that log sin 10'=7·19611969 843372. It will therefore be noticed that the log sines are in strictness given to 14 (and not 15) places. Further, it appears that the last figure has not been, or at all events not been always, corrected; for log sin 50^g= log $\frac{1}{\sqrt{2}}$=·3494850021680094O...., and the logarithm in [T. VII.] ends with the figures 6800. This is the only one we have examined.

At the end of [T. VII.] is given a page of tables to connect decimals of a right angle with degrees, minutes, and seconds, &c.

[T. VIII.] consists of proportional-part tables, and occupies 10 pp.: by means of them any number less than 10,000 can be multiplied by a single digit with great ease; the use of this in interpolation is evident. A full explanation is given on pp. 32–36 of the Introduction to the work.

[T. IX.] Log sines and tangents for every second of the first five degrees, to seven places, without differences (sexagesimal).

[T. X.] Log sines and tangents for every ten seconds of the quadrant, to seven places, with differences (sexagesimal).

[T. XI.] Logistic logarithms, viz. log $3600''$ − log x'' from $x=0''$ to $x=5280''=1^\circ\ 28'$; $3600''=1^\circ$.

The other tables have reference to Borda's method for the determination of the longitude at sea.

On the whole, this is the most complete and practically useful collection of logarithms for the general computer that has been published. In one not very thick octavo volume, 11 important tables are given; the type is very clear and distinct, though rather small. In the logarithms of numbers an attempt has been made to give rather too much on the page; but for *general* usefulness this collection of tables is almost unique.

The introduction, of 118 pp., is the worst portion of the work; it is badly arranged, confused, and, worst of all, has no index; so that it is very hard to find the explanation of any table required, if it is explained at all. On p. 112 the value of e is given; but the figures after the 8th group of five are erroneous, and should be 47093 69995 95749 66967 6....(see Brit. Assoc. Report, 1871, Transactions of Sections, p. 16).

On pp. 12 and 13 of the introduction are two tables that deserve notice: the first gives the square, 4th, 16th.... 2^{60}th roots of 10 to about 28 significant figures (leaving out of consideration the ciphers that follow the 1 in the higher powers). The second gives powers of ·5 as far as the 60th.

With regard to errors, an important list is given by Lefort in the 'Comptes Rendus,' vol. xliv. p. 1100 (1857); and these of course apply to the later *tirages*. Many errors of importance, as also some information as to the sources whence Callet derived his tables, are given. See also Gauss in Zach's 'Monatliche Correspondenz,' November 1802 (or 'Werke,' t. iii. p. 241), for four errata, and Gernerth's paper (referred to at the end of the introductory

remarks in § 3, art. 13), and also HUTTON's tables (editions 1783–1822). Gernerth remarks (p. 25) that errors pointed out by Hutton in 1822 still remained uncorrected in the tirage of 1846. We may also refer to a paper by Herrmann, entitled "Verbesserung der II. Callet'schen Tafel der gemeinen Logarithmen mit 20 Decimalen, nebst Vorschlagen für die weitere Förderung dieses Zweckes," printed in the 'Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften,' Vienna, 1848, part ii. pp. 175–190.

On p. liii of their work, HOBERT and IDELER (1799) remark that they found that in general the natural sines of Callet were calculated accurately, but that in the log sines the last two figures were generally doubtful; they mention also that they found many other faults in the work, but, being uncertain how far these are corrected in the stereotype edition, they only give one: viz., on p. 117 of the introduction, in the eighth place in the value of f there is a 2 for a 3; and this fault renders erroneous the multiples of f. A list of 380 errors is given on pp. 348 and 349 of the book, in all of which the error is $\pm$ 1 in the last place, and also an error in a natural sine is given. The above error in f is corrected in the tirage of 1853.

On p. 120 of BORDA and DELAMBRE there are given six errors in the stereotyped tables of Callet. A good many errors are also given at the end of VEGA's Manual (1800).

Many other errata are noted in other books; but it seems useless to give references without at the same time examining whether the errors have been subsequently corrected, and, if so, in what tirages.

Hobert and Ideler consider that Callet obtained his log sines most probably by interpolation from the 'Trigonometria Artificialis' of Vlacq.

The number of tirages of this work has been very great: it was first published in 1783, we believe; but the type from which the earlier tirages were printed was subsequently reset, as the size of the page in the editions published in this century is larger than that of the first, which had therefore more right to the title "Tables portatives." The tirage we have described above is that of 1853; and we have seen one of 1862, "revue par J. Dupuis" (Dupuis was himself subsequently the editor of a set of logarithmic tables, described in this section). There is also a still more recent edition, edited by M. Saigey. We have an impression that the CALLET of 1793 was the first logarithmic table stereotyped; but we have not investigated the matter.

Coleman, 1846. T. XIX. Log sines, tangents, and secants to every quarter point, to 6 places.

T. XX. Six-figure logarithms to 10,000, arranged in decades, with proportional parts above 1000.

T. XXI. *Logarithms for finding the apparent time or horary angle*, viz. log semi-versed sines $\left(=\log\dfrac{1-\cos x}{2}\right)$ from 0^h to 9^h, at intervals of 5^s, to 5 places, with proportional parts.

T. XXIII. Log sines, tangents, and secants for every minute of the quadrant, to 6 places.

T. XXIV. Proportional logarithms for every second to 3°; same as T. 74 of RAPER, only to 5 instead of 4 places. It must be observed that on the first page (extending to 10′) the logarithms are not given completely, the last figure, two figures, or three figures being printed as ciphers. This is done, we presume, because in the cases to which the table is intended to be applied accuracy in these places is not required. The same is done in several other copies of this table occurring in other nautical collections. Opposite 0 is given 4.88.. instead of $-\infty$. The other tables are nautical.

Croswell, 1791. T. I. Log secants, half log secants, and half log sines, viz. log sec x, $\frac{1}{2}$ log sec x and $\frac{1}{2}$ log sin x, to every minute of the quadrant, to seven places, the last two being separated by a comma for the convenience of those who only require five places; semiquadrantally arranged: no differences. The table, as headed in the book, implies that the tabular results are natural; but they are as above.

T. V. Proportional logarithms for every second to 3°, to 4 places: the same as T. 74 of Raper.

T. XIII. Small table to convert arc into time. The other tables are nautical.

De Decker, 1626. T. I. Ten-figure logarithms of numbers to 10,000, with characteristics and differences.

T. II. Logarithmic sines and tangents, to seven decimals, for every minute, from Gunter 1620 (§ 3, art. 15).

These tables were always assigned to Vlacq till, in the course of the preparation of this Report, it came to light that De Decker was the author, Vlacq having only rendered some assistance. For the history of them, as well as for their connexion with 'Tables des Logarithmes pour les nombres d'un à 10,000 composés par Henry Brigge,' Gouda, 1626, and the tables in Wells's 'Sciographia,' 1635, see Phil. Mag., October and December (Supp. No.), 1872, and May, 1873.

Degen, 1824. T. I. $\text{Log}_{10}(1 . 2 . 3 \ldots . x)$ is given from $x=1$ to $x=1200$, to 18 places. The complement of the logarithms from 100 is also added if the characteristic be less than 100—if not, the complement from 1000 or 10,000; thus log $(1 . 2 \ldots . 69)=98{\cdot}233 \ldots .$, and the complement is $1{\cdot}766 \ldots .$; log $(1 . 2 \ldots . 70)=100{\cdot}078 \ldots .$, and the complement is $899{\cdot}921 \ldots . .$ The first portion of this table is reprinted by De Morgan, to 6 places, in the 'Encyclopædia Metropolitana' (§ 3, art. 25).

T. II. The first hundred multiples of the modulus ·434 . . . , to 30 places.

T. III. The first nine multiples of log 2, log 3, log 5, log 6, log 7, log 11, log 12, log 13, log 14, log 15, log 17, log 18, log 19, log 21, log 22, log 23, log 24, log 26, log 28, and log 29 (Briggian).

The other tables consist of formulæ &c. There is a full introduction.

[**De Morgan**] 1839. [T. I.] Five-figure logarithms to 10,000 (arranged consecutively, and not as in seven-figure tables), with differences, and degrees corresponding to the first number in each column.

[T. II.] Logarithms from 1001 to 1100, to 7 places.

[T. III.] Log sines, cosines, tangents, and cotangents to every minute, to 5 places, with differences.

[T. IV.] Log sines for every second of the first nine minutes, and also for every tenth of a minute in the first degree.

[T. V.] A small table of constants; most of them taken from Babbage.

[T. VI.] Log $(1 . 2 . 3 \ldots . x)$, from $x=6$ to $x=25$, at intervals of unity, and thence to 265, at intervals of 5, these last three tables being also to 5 places.

The tables are beautifully printed, and are practically free from error. Prof. Wackerbarth states ('Monthly Notices of the Royal Astronomical Society,' April 1867) that he finds the only error in the work to be among the constants on p. 213, line 5, where 2·718281829 should be 2·718281828, the following figure being 4.

There is no name on the titlepage; but it is well known that the tables were prepared by De Morgan, and they are always spoken of by his name. They were examined by Mr. Farley of the Nautical-Almanac Office.

De Prasse, 1814. [T. I.] Five-figure logarithms of numbers to 339 (with characteristics), and thence to 10,000, arranged as is usual in seven-figure tables. When the fifth figure has been increased it is printed in different type. The change in the line is denoted by an asterisk prefixed to the third figure of all the logarithms affected.

[T. II.] Log sines and tangents for every minute to 5°, and thence for every ten minutes to 85°, when the intervals are again one minute to 90°, to 5 places. π and e, and nine multiples of the modulus and its reciprocal are given on the last page. The price is one franc.

A short review of this work, reprinted from the 'Göttingische gelehrte Anzeigen,' Dec. 19, 1814, will be found on p. 243 of t. iii. of Gauss's 'Werke.' On pp. 241–243 is also reprinted a review of the original edition (Leipzig), from the same 'Anzeigen' for May 25, 1811.

Dodson, 1747. T. XVII. Least divisors of numbers to 10,000 (multiples of 2 and 5 omitted).

T. XVIII. Primes from 10,000 to 15,000.

T. XIX. Square and cube roots (to 6 places) of numbers to 180.

T. XX. Combinations up to the combination of 34 things, 29 together: a table of double entry.

T. XXI. Powers of 2 to 2^{29} &c.

T. XXII. The first 20 powers of the 9 digits.

T. XXIII. *Permutations*, viz. $1 \,.\, 2 \ldots . x$, to $x=30$.

T. XXV. Circular measure of 1°, 2°,.... 180°; of 1′, 2′,.... 60′; of 1″ .... 60″; and of 1‴ .... 60‴: to 7 places.

T. XXVI. Versed sines of arcs, and the areas of the segments included by those arcs and their chords to every 15′ of the quadrant, to 7 places, with differences.

T. XXVII. The first 9 multiples of 12 constants (viz. $\pi, \frac{1}{\pi}, \frac{\pi}{4}, \frac{1}{4\pi}$, &c.), to 7 places.

T. XXVIII. Table of polygons, giving any three of the four quantities, length of side, radius of inscribed circle, radius of circumscribed circle, area, when the fourth is given$=1$, for polygons of less than 13 sides, to 7 places.

T. XXIX. Table of regular solids, giving any four of the five quantities, side, radius of circumscribed sphere, radius of inscribed sphere, superficies, solidity, when the fifth is given$=1$, to 7 places, for the 5 regular solids.

T. XXXII. Seven-figure logarithms to 10,000, with differences.

T. XXXIII. Antilogarithms, viz. numbers to logarithms from ·0001 to ·9999 at intervals of ·0001, to 7 places.

T. XXXIV. Log sines and tangents for every minute of the quadrant, to 7 places, with differences; but between 0° and 2° the differences between the logarithms of the arcs and the logarithms of the sines and tangents of those arcs are given instead.

T. XXXV. The number of seconds contained in any number of minutes less than 2°.

T. XXXVI. Logistic logarithms, viz. $\log 3600^{s} - \log x$ from $x=1$ to $x=4800^{s}$ $(=80^{m})$ (argument expressed in minutes and seconds), to 4 places.

T. XXXVII. *Neper's logarithms.* The table, however, is really one to convert common into hyperbolic logarithms, and is in fact, when so regarded, the first 1000 multiples of the reciprocal of the modulus, viz. 2·302..., to 6 places.

T. XXXVIII. Products to 9×9999.

There are, besides, very many other tables of all kinds, astronomical, commercial, &c.: we have described all the mathematical ones.

Domke, 1852. T. XXX. *Quadrate der Minuten des Stundenwinkels,* viz. $\left(x+\frac{y}{60}\right)^2$ from $x=1$ to $x=15$, and from $y=1$ to $y=60$, to one decimal place; thus corresponding to $8' 20''$ the table has 69·4; for $8' 20''=8\frac{1}{3}=$ 8·33 . . ., and its square, retaining one decimal place, is 69·4.

T. XXXII. Six-figure logarithms to 100, and from 1000 to 10,000, with differences: all the logarithms written at full length.

T. XXXIII. Log sines, tangents, and secants to every quarter point, to 6 places.

T. XXXIV. Log sines and tangents for every second, for the first two degrees, to 6 places: all the logarithms written at length.

T. XXXV. Log sines, tangents, and secants, to every minute of the quadrant (arguments also expressed in time), with differences, arranged semiquadrantally: all the logarithms written at length.

T. XXXVI. Natural sines to every minute of the quadrant, to 6 places, arranged quadrantally.

T. XXXVII. *Logarithmen der halbverflossenden Zeit,* viz. log cosec x from $x=0^h$ to $x=3^h\ 59^m\ 55^s$ at intervals of 5^s, to 5 places, with proportional parts for seconds.

T. XXXVIII. *Logarithmen der Mittelzeit,* viz. log 2 sin x, from $x=0^h$ to $x=3^h\ 59^m\ 55^s$ at intervals of 5^s, to 5 places, with proportional parts for seconds.

T. XXXIX. *Logarithmen des Stundenwinkels,* viz. log versed sine x, from $x=0^h$ to $x=7^h\ 59^m\ 55^s$ at intervals of 5^s, to 5 places, with proportional parts for seconds.

T. XL. Proportional logarithms for every second to 3°, to 4 places; the same as T. 74 of Raper.

T. XLVII. and XLVIII. occupy one page, and are for the conversion of arc into time, and *vice versâ.*

The other tables are nautical.

In all the tables the logarithms are written at full length; the type is thin and very clear, the figures having heads and tails.

T. XXX. was calculated from this work; T. XXXII., XXXIII., and XXXV.–XL. were taken from Norie's 'Epitome of Navigation,' (they are Maskelyne's tables; but see Bowditch, 1802, T. XIII.) and T. XXXIV. from Callet.

On the accuracy of this work see the tract of Gernerth's referred to in § 3, art. 13 (p. 55). There was a second edition in 1855 (Gernerth).

Donn, 1789. T. I. Seven-figure logarithms to 10,000, with differences.

T. II. Log sines and cosecants to every quarter point, to 7 places.

T. III. Log sines and tangents and natural sines for every minute of the quadrant, to 7 places.

T. IV. Log $\frac{1}{2}$ elap. time, mid time, and rising (see explanation of the terms under T. XVI. of Maskelyne, 1802), for every half minute to 6^h, to 5 places.

T. V. Log versed sines and natural tangents and secants for every 10′ of the quadrant, to 4 places.

The other tables are nautical.

We have also 'The British Mariner's Assistant, containing forty Tables. .' London, 1774, 8vo (352 pp. of tables), the tables of which are the same as those described above.

Douglas, 1809. [T. I.] and T. I. Supplement, and T. II. Supplement. Logarithms of numbers to 10,999, and from 100,000 to 101,009, to 7 places (without differences).

[T. II.] Log sines, tangents, and secants for every minute of the quadrant, to 7 places (without differences).

[T. III.] Natural sines, tangents, and secants for every minute of the quadrant, to 7 places (without differences).

[T. IV.] Natural and log versed sines to every minute, from 0° to 180°, to 7 places (without differences).

T. III. Supplement. Table to convert sexagesimals into decimals. It gives 1″, 2″, 4″ . . . 58″, 1′, 1′ 1″, 1′ 2″, 1′ 4″. . . 1′ 58″, 2′ . . . 2′ 58″, &c. to 60′, expressed as decimals of 60′, to 4 places.

T. IV. Supplement. Logarithms of numbers from 1 to 180, to 15 places.

Ducom, 1820. T. VII. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of Raper.

T. IX. Log sines and tangents for every second to 2°; then follow log cosines and cotangents for every 10″ to 2°; and then log sines, cosines, tangents, and cotangents from 2° to 45°, at intervals of 10″, to 6 places. Proportional parts are added for the portion where the intervals are 10″.

T. XIX. Natural sines for every minute of the quadrant, to 6 places.

T. XX. *Parties proportionnelles* for interpolating when the tabular result is given for intervals of 24^h, viz. $\frac{x,y}{24^h}$ (expressed in hours, minutes, and seconds), where x is $1^m, 2^m, \ldots 60^m$, and, in the first table, y is $1^h, 2^h, \ldots 24^h$, and in the second $1^m, 2^m, \ldots 60^m$.

T. XXI. Six-figure logarithms of numbers to 10,800, with corresponding minutes and seconds: logarithms printed at full length; no differences. The other tables are nautical &c.

The tables form the second part of the work. It may be noticed that, in the remarks on T. XIX. (p. xiv), the versed sine of x is erroneously defined as if it were $1-\sin x$.

Dunn, 1784. [T. I.] Six-figure logarithms to 10,000. The arrangement is the same as is usual in seven-figure tables; only instead of the numbers 0, 1, 2, ... 9 running along the top line, they are printed 0·00, 1·00, 2·00, ... 9·00, which gives the table the appearance of being arranged differently.

[T. II.] Log sines, tangents, and secants to every minute of the quadrant, to 6 places. At the foot of each page is a small table, giving the differences (for the sine and tangent) for an interval of 60″ in the middle of the page, and their proportional parts for 50″, 40″, 30″, 20″, 10″, 9″, 8″, 7″, 6″, 5″, 4″, 3″, 2″, 1″. At the end is a table of the differences of the log sines, tangents, and secants for every 10′.

Dupuis, 1868. T. I. & II. Seven-figure logarithms from 1 to 1000, and from 10,000 to 100,000. Proportional parts *to tenths*, viz. multiples with the last figure separated by a comma, are added. (The separation of the last figure is an improvement on the simple multiples given in Sang, 1871, and others, as the table can be more readily used by those accustomed only to proportional parts true to the nearest unit.) S and T (§ 3, art. 13) are given at the bottom of the pages at intervals of 10″. Dupuis states in the preface that his intention had been that the table should extend to 120,000, and that accordingly he had calculated the last 12,000 logarithms by differences, but at the request of a number of professors he stopped at 100,000. We venture to think he would have acted more wisely if he had not listened to the professors*; but the matter is of no consequence now, as Sang, 1871, extends to 200,000,

* Several of the ordinary seven-figure tables (Babbage, Callet, Hülsse's Vega, and many others) extend to 108,000, and the last 8000 logarithms are given to eight places.

T. III. Hyperbolic logarithms to 1000, to 7 places.

T. IV. & V. First hundred multiples of the modulus and its reciprocal, to 7 places.

T. VI. & VII. Log sines and tangents for every second to 5°, to 7 places, with negative characteristics (viz. 10 *not* added).

T. VIII. Log sines, tangents, cotangents, and cosines (arranged in this order) from 0° to 45° at intervals of 10″, with negative characteristics, to 7 places; with differences and proportional parts, as before, to tenths.

T. IX. Circular measure of 1°, 2°,....180°, 1′....60′, 1″....60″, to 7 places.

T. X. (réduction des parties de l'équateur en temps); hours and minutes (or minutes and seconds) of time in 1°, 2°,....360° (or 1′....360′), and seconds of time in 1″, 2″,....60″, to 7 places; then follows an explanation of the use of the tables.

This is the only work we can call to mind in which negative characteristics (with the – sign printed over the figure) are given throughout; and to the mathematical computer such are preferable to the ordinary characteristics increased by 10. Also the edges of the pages of T. VI.–VIII. are red (the rest being grey), which facilitates the use of the tables. It is curious that it never should have occurred to any editor or publisher of a collection of tables to colour the edges of the pages of the separate tables differently, and print thereon also their titles, as is done with the different businesses &c. in the London Post-Office Directory.

Dupuis was also the editor of the 1862 edition of CALLET; and the titles of several small tables of logarithms that we have not seen are advertised in this work, viz.:—(1) an edition of Lalande's five-figure tables, with Gaussian logarithms added, &c.; (2) an 18mo book of four-figure tables; and (3) logarithmic and antilogarithmic tables to 4 places, for the use of physicists, giving log $(1+at)$ for the calculation of dilatations &c.

[**Encke,** 1828.] [T. I.] Four-figure logarithms to 100 (with characteristics and differences), and from 100 to 1009.

[T. II.] Log sines, tangents, cotangents, and cosines for every 4′ from 0° to 10°, and thence to 45° at intervals of 10′, to 4 places, with differences.

[T. III.] Gaussian logarithms; B and C are to 4 places, for argument A, from A=·00 to 1·80 at intervals of ·01, and thence to 4·0 at intervals of ·1, with differences.

Encke's name is written on the Royal Society's copy of these tables; and they are also spoken of as Encke's by De Morgan. They are reprinted in WARNSTORFF'S SCHUMACHER, 1845 (§ 4).

Everett [1866]. Two cards (one of which, unfolded, is equal in size to three folio pages, the other, which is equal in size to one, being perforated), in a cover.

This very frequently gives rise to errors, as the computer who is accustomed to three leading figures common to the block of figures is liable to fail to notice that in this part of the table there are four; and on this account a figure (the fourth) is sometimes omitted in taking out the logarithm. It is therefore often desirable to ignore the continuation of the table and only use the portion below 100,000. The extra logarithms are thus not always an advantage; and it is on the face of it inconvenient that some of the tabular results should be given to 7 and others to 8 places. When tables of logarithms are placed in the hands of common computers, it is as a rule better to forbid the use of the portion beyond 100,000; and it may have been some considerations of this nature that induced M. Dupuis to take this number as his limit. But there is no objection that we can see against giving the logarithms beyond 100,000 to 7 places (as in SANG, 1871); and whenever this is done, the continuation is found very useful.

These cards correspond to the fixed and movable portions of a slide-rule 160 inches long. A few small tables of cube roots, sines, &c. are printed on one of the cards. Prof. Everett (to whom we applied for information with regard to the date of the table) gives the following brief description—"Two cards, one of them cut like a grating, equivalent to the two pieces of a slide-rule;" and adds "that in the first edition [which is the one we have described] one of the cards had a pair of folding leaves attached to it, but these merely contained subsidiary tables and directions, and were quite unessential. In the next impression the two essential cards and the two cards with subsidiary tables and directions were all detached from each other." A description of the table is given in the Phil. Mag. for November 1866.

Farley, 1840. [T. I.] Six-figure logarithms to 10,000 (the line is broken when the change occurs in the third figure); followed by the logarithms of numbers from 1001 to 1200, to 7 places.

[T. II.] Log sines and tangents for every minute of the quadrant, to 6 places, with differences for 100″.

[T. III.] Log sines from 0° to 2° at intervals of 6″.

There are also a few constants and some formulæ.

Farley, 1856. This very fine table of versed sines contains:—[T. I.] Natural versed sines from 0° to 125° at intervals of 10″, to 7 places, with proportional parts throughout.

[T. II.] Log versed sines from 0° to 135° at intervals of 15″, to 7 places, with differences throughout. The arguments are also given in time, the range being from 0^h to 9^h to every second.

A short preface by Mr. Hind states that the table was prepared by Mr. Farley, of the Nautical-Almanac Office, in 1831, and the manuscript presented by him to Lieut. Stratford, the then superintendent. The manuscript having been in use for 25 years, and having become dilapidated, it was "deemed the most economical course to print it." It is added that the last figure cannot be relied on, though it is probably very rarely in error by more than a unit.

These, the most complete tables of versed sines we have seen, are beautifully printed, in the same type as the Nautical Almanac.

Faulhaber, 1630 ('Ingenieurs-Schul'). The copy we have seen of this book (viz. that in the British Museum) contains no logarithms, though it must evidently have been intended to accompany some tables. In the Brit-Mus. copy the work is bound up (in a volume containing four tracts) after the two described below and attributed by us to Faulhaber. Murhard gives the full titles of this work and of the next two, and marks them as having come under his eye; he does not, however, assign the two tables to Faulhaber. Rogg, who also gives the titles of the three works, attributes them all to Faulhaber. He adds, speaking of the tables, that they are also contained in the 'Ingenieurs-Schul.' This is no doubt correct; for, as noted below, some errors in the latter work are given at the end of the Canon. It seems therefore certain that Faulhaber was the editor of the tables. It may be mentioned that both Rogg and Murhard agree in describing the 'Logarithmi' and the 'Canon' as parts of the same work, so that most likely they were never issued separately. Rogg gives the date of the 'Ingenieurs-Schul' as 1731, which must be a misprint for 1631; the copy before us is dated 1630, agreeing with Murhard. A lengthy account of Faulhaber and his works will be found in Kästner's 'Geschichte.' See also Scheibel, 'Math. Bücherk.' B. 2. p. 39.

[**Faulhaber**] 1631 ('Logarithmi'). Seven-figure logarithms of numbers from 1 to 10,000, arranged in columns (three to the page), with characteristics. As there are 3 columns, there are 99 logarithms on each page. The printing is imperfect, the types having here and there become displaced, so as to leave no mark. There are some errata on the last page, headed "Typographus Lectori S." See above, FAULHABER, 1630 ('Ingenieurs-Schul').

[**Faulhaber**] 1631 ('Canon'). Logarithmic sines, tangents, and secants for every minute of the quadrant, to 10 places (semiquadrantally arranged); no differences. Taken from VLACQ, 1628. The table is followed by 8 pages of errata in the Frankfort 'Ingenieurs-Schul,' in the logarithms of numbers, and in the 'Canon.' Except perhaps NORWOOD, 1631, this is the first reprint of VLACQ's corrected 'Canon' (1628), the previous writers having copied GUNTER (1620). Rogg gives place and date as Nuremberg, 1637; but the copy before us is not so. See above, FAULHABER, 1630 ('Ingenieurs-Schul').

Filipowski, 1849. T. I. Antilogarithms. The numbers (to 7 figures) are given answering to the logarithms as arguments, the range being from ·00000 to 1·00000 at intervals of ·00001. The arrangement is exactly the same as in ordinary seven-figure tables of logarithms; and the table occupies 201 pages. The proportional parts are given to hundredths (viz. 100 proportional parts of each difference are given); and the change of figure in the middle of the line is denoted by two dots (thus, $\ddot{0}$) placed over the fourth figure of all numbers affected; and when a final 5 has been increased it is printed V. The first 3 figures in the number are always separated by a space from the block of figures.

T. II. Gaussian logarithms, arranged in a new way. Let $\Delta = \log x$ and $\lambda = \log(x+1)$ (so that $10^{\lambda} = 10^{\Delta} + 1$), then on the first page of the table (p. 203 of the book) we have Δ given to 3 places for argument λ from $\lambda = \cdot 00000$ to $\cdot 00449$ (which last corresponds to $\Delta = 8\cdot 017$), at intervals of ·00001. On the succeeding 16 pages we have λ as a tabular result for argument Δ from $\Delta = 8\cdot 000$ to $13\cdot 999$, at intervals of ·001, to 5 places.

Since
$$\log(a+b) = \log b + \log\left(\frac{a}{b}+1\right), \text{ and}$$
$$\log(a-b) = \log b + \log\left(\frac{a}{b}-1\right),$$
it is clear that the rules are very simple and uniform, viz. $\log a$ and $\log b$ being given ($b < a$ suppose), we take $\log a - \log b$ as argument, and enter the table at the Δ or λ column, according as we want $\log \overline{a+b}$ or $\log \overline{a-b}$, and add the tabular result to $\log b$. In this table also the notations $\ddot{0}$, V, &c. are used, as well as another in which a wavy line runs down by the side of the logarithms whose leading figures have changed. This method of marking is only possible when the tabular results appear one under the other. The figures are throughout neat and clear, having heads and tails; and the copy before us is printed on green paper, of a pleasant colour. In many places there is a parsimony of figures, which we dislike extremely; thus there occur 44, 5, 6 as headings for 44, 45, 46, and 0 or $\ddot{0}$ for 10 &c. A list of 36 errors affecting the first 8 figures of DODSON's Canon (1742) is given, and introduced by the remark, "The following is a list of errors as detected, by means of our table, in the first 8 places of Dodson's Anti-Logarithmic Canon, in addition to those corrected with the author's own hand." These words im-

ply that Mr. Filipowski's table was the result of an independent calculation; or at all events they ought not to have been written unless such had been the case. It is, however, nowhere stated in the preface that the table was calculated anew; and we may therefore assume that it was copied from Dodson, after examination (which would not have been difficult, as a mere verification by differences would have sufficed). In a letter by Mr. Peter Gray, in the 'Insurance Record' for June 9, 1871, there are given two errors in Dodson which also occur in Filipowski, affording additional evidence that the tables of the latter were not calculated independently; and, this being so, Dodson has not been treated fairly, as Mr. Filipowski should have acknowledged the obligations he was under to his table. In the same letter Mr. Gray gives three other errors in Filipowski (1st edit.); and it is to be inferred from other passages in the letter that a second and a third edition, "corrected," have been published. Mr. Gray proceeds:—"but he [Filipowski] has never, so far as I know, given a list of the errors contained in the first and second, and corrected in the third," an omission on which he strongly (and most justly) animadverts. See SHORTREDE (1849).

De Morgan has stated that no antilogarithmic table was published from DODSON (1742) till 1849; but this is only true if SHORTREDE's tables of 1844 be ignored; for which there is no sufficient reason, as they were published and sold in that year, and copies of the 1844 edition are contained in all good libraries.

Galbraith, 1827. T. II. Six-figure logarithms of numbers to 10,000, with proportional parts on the *left-hand* side of the page. This table is headed "Logarithms of numbers to 100,000."

T. IV. Log sines, tangents, and secants to every quarter point, to 6 places.

T. V. Log sines, tangents, and secants to every minute of the quadrant (arguments expressed also in time, the intervals being 4^s), with differences, to 6 places.

T. VI. Natural sines, tangents, secants, and versed sines to every degree of the quadrant, to 6 places.

T. IX. *Diurnal logarithms*: proportional logarithms for every minute to 24^h (viz. $\log 1440 - \log x$) from $x=1$ to $x=1440$ (expressed in hours and minutes), to 5 places.

T. X. Proportional logarithms for every second to 3°, to 5 places. Same as T. 74 of RAPER, except that 5 instead of 4 places are given.

T. LXIII. A few constants. The other tables are nautical.

There are a few small tables in the introduction that may be noticed, viz.:—T. XI. and XII. (p. 113), to express hours as decimals of a day, convert time into arc, &c.; T. XV. (p. 141), of the areas of circular segments (same as in T. XIII. of HANTSCHL, but to hundredths only, and to 5 places); and T. XVI., table of polygons (as far as a dodecagon), giving area, and radius of circumscribing circle for side=unity, and factors for sides, viz. length of side for radius=unity; there are also one or two small tables for the mensuration of solids.

Galbraith and Haughton, 1860. [T. I.] Five-figure logarithms to 1000, arranged in columns. This is followed by a small table to convert common into hyperbolic logarithms, and *vice versâ*.

[T. II.] Five-figure logarithms from 1000 to 10,000, with proportional parts.

[T. III.] Log sines and tangents to every minute of the quadrant, to 5 places, with differences.

[T. IV.] Gaussian logarithms. B and C are given for argument A, from

$A = \cdot000$ to $A = 2\cdot000$ at intervals of $\cdot001$, thence to $3\cdot40$ at intervals of $\cdot01$ and to 5 at intervals of $\cdot1$ to 5 places, with differences. This table is followed by a page of constants.

Gardiner, 1742. [T. I.] Seven-figure logarithms to 1000, and from 10,000 to 100,100, with proportional parts; the change of the fourth figure in the line is not marked; the first three figures of the logarithm are separated from the block of figures by a point, which is very clear.

[T. II.] Log sines to every second to 1′ 12″, to 7 places, without differences; and log sines and tangents throughout the quadrant at intervals of 10″, to 7 places, with differences.

[T. III.] Four-figure logistic logarithms, viz. $\log. 3600'' - \log x$ from $x = 0$ to $x = 4800''$ ($= 80'$) at intervals of 1″.

[T. IV.] Twenty-figure logarithms to 1000, thence of odd numbers to 1069, and of primes &c. to 1143.

[T. V.] Twenty-figure logarithms of numbers from 101,000 to 101,139, with first, second, and third differences.

[T. VI.] Anti-logarithms, viz. numbers to logarithms from $\cdot00000$ to $\cdot00139$ at intervals of $\cdot00001$, to 20 places, with first, second, and third differences.

A list of errata is given in the French reprint described below; and 69 errors are pointed out by Hutton on p. 342 of the edition of 1794 (and no doubt in other editions) of his mathematical tables. The list given in the edition of 1822 (the last published in Hutton's lifetime) is much fuller. De Morgan speaks of Gardiner as "rare, and much esteemed for accuracy;" and its rarity in 1770 is the reason assigned by the French editors for the necessity of reprinting it.

Gardiner (Avignon Reprint, 1770). The reprint is so similar to the original edition that it is only necessary to point out the differences.

[T. I.] is the same; but in [T. II.] the log sines are given at intervals of 1″ as far as 4°, and a similar table of log tangents is added; they were taken from a manuscript calculated by Mouton, bequeathed by him to the Academy of Sciences, and lent to the editors by Lalande. Also in the original edition, in the second portion of this table, viz. that giving the functions at intervals of 10″, the parts common to both are repeated; but this is not done in the reprint, in which therefore there is a table of log cosines and cotangents only, from 0° to 4°, at intervals of 10″, the sines and tangents being given in the previous portion.

[T. III., V., and VI.] are unaltered; but [T. IV.] proceeds by odd numbers to 1161. One fresh table is added, viz. [T. VII.], giving hyperbolic logarithms from $1\cdot00$ to $10\cdot00$ at intervals of $\cdot01$, to 7 places, and also $\log_e 10^2, \ldots 10^5$. Mouton's manuscript also gave log cotangents and cosines to every second of the first four degrees; but the former are so easily deducible from the tangents, and the latter vary so slowly, that their publication *in extenso* seemed unnecessary. A page of errata at the end of the book contains errors in Vlacq (1628), in Gardiner (1742), and in the French reprint itself (1770), the last having been published in the 'Connaissance des Temps' for 1775. As the 'Connaissance des Temps' could not have been published as much as five years in advance, it is clear either that some copies of the French reprint were published subsequently to 1770, although retaining that date on the titlepage, or that this page was circulated separately and bound up afterwards with the work. We have examined two copies, in one only of which this errata-page appears.

No editors' names appear in the work; but Lalande (Bibliog. Astron. p. 516)

says that this edition was edited by Père Pezenas, Père Dumas, and Père Blanchard, and adds that he has given an errata-list in the 'Connaissance des Temps' for 1775. On Dumas, mathematician of Lyons, who was Lalande's first master, he gives a reference to the 'Journal des Savants,' November 1770.

The edition is very commonly known by the name of Pezenas. A good deal about Pezenas will be found in Delambre's 'Histoire de l'Astronomie,' pp. 368–386. He was born at Avignon in 1692, and died in 1776.

The French edition is even better printed than the original, but is not quite so accurate. A list of 85 errors is given by Hutton on p. 343 of his mathematical tables in the edition of 1794, while he discovered only 69 in the original edition; more complete lists are to be found in the later editions.

Graesse ('Trésor') says that there was a reprint of Gardiner in octavo at Florence by Canovai and Ricco.

***Gardiner** (Paris edition, 1773). Rogg gives the title of a Paris edition of Gardiner, viz. 'Tables des Logarithmes de Gardiner, fol., Par. Chez Saillard et Nyon, 1773,' which he takes from the 'Journal litteraire de Berlin,' t. vii. p. 318; but the fact that Lalande does not mention it seems to him very suspicious: we have seen no other reference to it, and agree with Rogg.

Garrard, 1789. This work contains only traverse and meridional part tables. It is referred to here, as its title would imply that it was included in the subject of the Report.

Gordon, 1849. T. IX. Log sines, tangents, and cosecants for every minute from 6° to 90°, to 4 places.

T. X. Proportional logarithms for every second to 3°, to 4 places: same as T. 74 of Raper.

T. XI. Small table to convert space into time.

T. XVII. Half-sines and half-cosines, viz. halves of natural sines for every minute of the quadrant to four places, reckoned as seconds for the purpose of adapting them to the table of proportional logarithms: thus, corresponding to 12° 40′ we find as tabular result 18′ 16″; for the number of seconds in this angle$=1096$, and $\frac{1}{2}\sin 12° 40' = \cdot 1096$ . . .

T. XVIII. *Logarithms of the meridian distance*, viz. $\log (\frac{1}{2} \text{ vers sin } x)$, from $x=0^{h}$ to $x=7^{h}\ 59^{m}\ 55^{s}$ at intervals of 5^{s}, to 4 places.

T. XIX. Proportional logarithms for every minute to 24^{h}, viz. $\log 1440 - \log x$ from $x=1$ to $x=1440$, to 4 places (arguments expressed in hours and minutes).

T. XXI. Proportional logarithms for one hour, viz. $\log 3600 - \log x$ from $x=1$ to $x=3600$, to 4 places (arguments expressed in minutes and seconds).

The other tables are nautical.

Gregory, Woolhouse, and Hann, 1843. T. VIII. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of Raper.

T. IX. Log sines, tangents, and secants for every minute of the quadrant, to 5 places.

T. X. Natural sines to every minute of the quadrant, to 5 places.

T. XI. Five-figure logarithms from 1000 to 10,000, with proportional parts.

T. XII. Proportional logarithms for every minute to 24^{h}, to 4 places, viz. $\log 1440 - \log x$ from $x=1$ to 1440 at intervals of unity (arguments expressed in hours and minutes).

The other tables are nautical.

Griffin, 1843. T. 16. Log sines, tangents, and secants to every quarter point, to 6 places.

T. 17. Six-figure logarithms of numbers to 100, and from 1000 to 10,000, to 6 places, with differences.

T. 18. Log sines, tangents, and secants to every minute of the quadrant (arguments expressed also in time), to 6 places, with differences for the sines and tangents; arranged semiquadrantally.

T. 19. Natural sines to every minute of the quadrant, to 6 places, without differences.

T. 41. Proportional logarithms to every second to 3°, to 4 places; same as T. 74 of RAPER.

The logarithms are in all the tables printed at full length. The other tables are nautical.

Gruson, 1832. T. I. Seven-figure logarithms to 10,000: no differences. The change in the line is marked by a difference of type in all the logarithms affected. In three or four parts of the book this table is stated to extend to 10,100, but the limit is as above; and there is no possibility of a page having been torn out, as the next table is printed on the back of the page ending with the number 9999.

T. II. & III. Squares and cubes of all numbers from 1 to 1000.

T. IV. & V. Square and cube roots of all numbers from 1 to 1000, to 7 places.

T. VI. Circular measure of 1°, 2°, 3° . . . 360°, of 1′, 2′, . . . 60′, and of 1″, 2″, . . . 60″, to 7 places.

T. VII. Natural and log sines, cosines, tangents, cotangents, secants, and cosecants, to 7 places, with differences from 0° to 5° at intervals of 1′, and thence to 45° at intervals of 10′.

The book was intended for schools.

Hantschl, 1827. T. I. Five-figure logarithms (written at full length) of numbers from 1000 to 10,000.

T. II. Log sines for every 10 seconds from 0° to 90°, to 6 places.

T. III. Log tangents for every 10 seconds from 0° to 90°, to 6 places.

T. IV. Ten-figure logarithms of primes to 15,391.

T. V. Natural sines, tangents, secants, and versed sines for every minute of the quadrant, to 7 places; arranged semiquadrantally.

T. VI. Hyperbolic logarithms of numbers to 11,273, to 8 places.

T. VII. Least divisors of numbers to 18,277 (multiples of 2, 3, 5, and 11 excluded).

T. VIII. Squares, cubes, square and cube roots (to 7 places) to 1200.

T. IX. $\frac{n(n-1)}{1.2}, \ldots \frac{n(n-1)\ldots(n-5)}{1.2\ldots6}$ from $n=0$ to $n=1{\cdot}00$ at intervals of ·01, to 7 places.

T. X. Circular measure of 1°, 2°, 3°, . . . 180°, of 1′, 2′ . . . 60′, and of 1″, 2″ . . . 60″, to 15 places.

T. XI. The first nine multiples of

$$\pi,\ \frac{1}{\pi},\ \frac{\pi}{4},\ \frac{\pi}{6},\ \frac{1}{4\pi},\ \frac{\pi}{12},\ 2\left(\frac{1}{\pi}\right)^{\frac{1}{2}},\ \left(\frac{\pi}{6}\right)^{\frac{1}{3}},\ \text{and}\ \left(\frac{\pi}{6}\right)^{-\frac{1}{3}},$$

to 24 or 21 places.

T. XII. Small table to express minutes and seconds as decimals of a degree.

T. XIII. Areas of segments of circles for *diameter* unity to 6 places: the

versed sines are the arguments; and the table proceeds from ·001 to ·500 (of the diameter). The table may therefore be described as giving $\frac{1}{8}(2\theta-\sin 2\theta)$ from $\frac{1}{2}(1-\cos\theta)=\cdot001$ to ·500 at intervals of ·001.

A few constants are then given to a great many places; and the last page (T. XIV.) is for the calculation of logarithms to 20 places.

The work is clearly printed.

Hartig, 1829. The tables are of so commercial a kind that only one or two deserve notice here.

The first (T. I.) is for computing the contents of planks &c., the thickness and breadth being given in Zolle and the length in Fusse, and may be described as a *sort* of duodecimal table, as the Kubik-Zoll $=\frac{1}{12}$ Kubik-Fuss, and the Kubik-Linie $=\frac{1}{12}$ Kubik-Zoll. Thus for arguments 3 Zoll, 13 Zoll, and 5 Fuss we have 1 F. 4 Z. 3 L. as result; for $\frac{3}{12}\times\frac{13}{12}\times5=\frac{195}{144}=1+\frac{4}{12}+\frac{3}{144}$. The arguments are:—(thickness) 1 Zoll to 9 Zoll at intervals of $\frac{1}{2}$ Zoll; (breadth) 1 Zoll to 18 Zoll at intervals of 1 Zoll; (length) 1 Fuss to 60 Fuss at intervals of 1 Fuss.

Another table (T. II.) is of the same kind, only intended for blocks &c.; so that the thickness is greater, and the result is only given in fractions of a Kubik-Fuss.

T. III. contains volumes of cylinders for diameter (or circumference) of section and length as arguments; expressed as in T. I. and II. The money-tables can have no mathematical value, as the Thaler $=30$, 24, or 90 Groschen, &c.

T. X. is for the calculation of interest. The simple-interest tables (T. A) are too meagre to be worth description. T. B and C may be described as giving the compound interest and present value of £1 for any number of years up to 100 at 3, 4, 5, and 6 per cent. per annum, viz.

$$\left(1+\frac{x}{100}\right)^n \text{ and } \left(1+\frac{x}{100}\right)^{-n},$$

to 6 decimal places.

Other tables of this kind that we met with have not been noticed; the title of one such is given under JAHN, 1837.

Hassler, 1830. [T. I.] Seven-figure logarithms of numbers from 10,000 to 100,000, with proportional parts. The line is broken for the change in the third figure, as in CALLET.

[T. II.] Log sines and tangents for every second of the first degree, to 7 places.

[T. III.] Log cosines and cotangents for every 30″ of the first degree, to 7 places, with differences.

[T. IV.] Log sines, cosines, tangents, and cotangents, from 1° to 3°, at intervals of 10″, with differences, and from 3° to 45°, at intervals of 30″, with differences for 10″, to 7 places.

[T. V.] Natural sines for every 30″ of the quadrant, with differences for 10″, to 7 places.

Copies of this book were published with Latin, English, French, German, and Spanish introductions and titlepages (the titles will be found in the list at the end of the Report). The tables are the same in all; and the special titlepages for each table have the headings in the five languages. The Royal Society's library contains the Latin copy perfect, and the introductions in the four modern languages bound together in another volume, presented to the Society by the author. At the end of the latter volume is pasted-in a specimen page of the table, set up with the usual even figures;

and the author has written on the back, "This sheet proves that, with the usual form of figures of the same size as those used in the tables, they would not have been distinctly legible." The figures actually used are very thin, and have large heads and tails, resembling somewhat figures made in writing; and a comparison of the specimen and a page of the tables shows very clearly the superiority of the latter in point of distinctness. The words *in minima forma* are quite justified, as we do not think it would be possible to make the tables occupy less room without serious loss of clearness. All that is usually given in a page of seven-figure logarithms is here contained in a space about 3 in. by 5 in.; and yet, owing to the shape of the figures, every thing is very distinct. The author says on the titlepage, "*purgatæ ab erroribus præcedentium tabularum*;" but the last figure of log 52943 is printed 6 instead of 5. There is also another last-figure error. See 'Monthly Notices of the Roy. Ast. Soc.,' March 1873.

A short review of this work by Gauss appeared in the 'Göttingische gelehrte Anzeigen,' March 31, 1831 (reprinted 'Werke,' t. iii. p. 255).

Henrion, 1626. [T. I.] Logarithms to 20,001, to 10 places, with interscript differences (characteristics not separated from the mantissæ), copied from BRIGGS, 1624.

[T. II.] Log sines and tangents for every minute, to 7 places (characteristics unseparated from the mantissæ), taken from GUNTER, 1620. HENRION had calculated some logarithms himself when he received BRIGGS's work (see Phil. Mag., Supp. No. Dec. 1872). The copy of HENRION we have seen is in the Brit. Mus. The full titlepage is given in § 5.

Hentschen (Vlacq), 1757. [T. I.] Natural sines, tangents, and secants, and log sines and tangents to every minute, to 7 places (arranged on what De Morgan calls the *Gellibrand model*) (180 pp.), and [T. II.] logarithms of numbers to 10,000, to 7 places, arranged in columns (100 pp.).

A former edition of 1748 is spoken of in the preface; and it is stated that the tables were compared with the editions of Vlacq, Leyden, 1651, the Hague, 1665, and Amsterdam, 1673. The type is very bold and clear, much easier to read than in most modern tables.

This is one of the numerous series of small tables known by the name of Vlacq, and is described here because it is not mentioned by De Morgan; small editions like the present are so difficult to meet with that it is desirable to notice them whenever any are found.

Hobert and Ideler, 1799. [T. I.] Natural and log sines, cosines, tangents, and cotangents for the quadrant, divided centesimally; viz. these functions are given for arguments from ·00001 to ·03000 of a right angle at intervals of ·00001 of a right angle, and from ·0300 to ·5000 of a right angle at intervals of ·0001, to 7 places, with differences. Expressed in grades (centesimal degrees) &c., the arguments proceed to 3^g at intervals of 10'', and thence to 50^g at intervals of 1'. The manner of calculation of the table is fully explained in the introduction; and this adds much to the value of the work. Several of the *fundamenta* were calculated to a great many places. Two or three constants are given on p. 310.

B. Table of natural sines and tangents for the first hundred ten-thousandths (viz. for ·0001, ·0002 &c.) of a right angle, to 10 places.

C. Four tables, expressing (I.) 1°, 2°, 3°,....89°, (II.) 1′, 2′,....59′, (III.) 1″, 2″,....59″, (IV.) 1‴, 2‴,....59‴, all as decimals of 90°, to 14 places.

D. Three tables to express (I.) hundredths, (II.) thousandths, (III.) ten-thousandths of 90°, in degrees, minutes, and seconds (sexagesimal).

E. Four tables to express (I.) hours, (II.) minutes, (III.) seconds, (IV.) thirds, as decimals of a day.

F. Small table to express decimals of a day, in hours, minutes, and seconds.

G. Circular measure of ·1, ·2,. . . . ·9, 1·0, of a right angle, to 44 places.

[T. III.] Logarithms of numbers to 1100, and from 999,980 to 1,000,021, to 36 places.

The work concludes with two remarkable lists of errata found in the course of the calculations, viz. 381 errors in the trigonometrical tables of Callet, all of which, with one exception, affect only the last figure by a unit, and 138 similar errors in Vega's 'Thesaurus,' 1794. The errors in Callet have, we presume, been corrected in the later *tirages*.

Hoüel, 1858. T. I. Five-figure logarithms of numbers to 10,800 with the corresponding degrees, minutes and seconds, and proportional parts. The constants S and T (see § 3, art. 13) are given at the top of the page; then follows a page of small tables for the conversion of degrees, minutes, &c.

T. II. Natural and log sines, tangents, and secants to every minute of the quadrant, to 5 places, with proportional parts.

T. III. Gaussian logarithms. The addition and subtraction tables are separated, as in Zech (§ 4). In the first B is given for argument A, from A = ·000 to 1·650 at intervals of ·001, thence to 3·00 at intervals of ·01, and thence to 5·0 at intervals of ·1. In the second B is given for argument C, from C = ·3000 to ·4800 at intervals of ·0001, thence to 1·500 at intervals of ·001, thence to 3·10 at intervals of ·01, and to 5·0 at intervals of ·1, with proportional parts: all to 5 places. These tables are followed by the first hundred multiples of the modulus and its reciprocal, to 8 places.

T. IV. Tables to calculate logarithms to 8 places &c.

T. V. (one page). To calculate logarithms to 20 places.

T. VI. A page of four-figure logarithms to 600, and of three-figure anti-logarithms.

T. VII. Least factors of composite numbers (not divisible by 2, 3, 5, or 11) up to 10,841.

T. VIII. A page of constants. [We have since obtained a "nouvelle édition, revue et augmentée," Paris, 1871, pp. 118 and introduction xlvi.]

Hülsse's Vega, 1840. T. I. Seven-figure logarithms to 1000, and from 10,000 to 108,000, with proportional parts; the change in the line is denoted by a small asterisk prefixed to the fourth figure of all the logarithms affected. The portion from 100,000 to 108,000 is given to 8 places. One page at the end is devoted to a small table to convert common into hyperbolic seven-figure logarithms, and *vice versâ*.

T. II. Log sines, tangents, and arcs (all equal) to every tenth of a second to 1′; log sines and tangents from 0° 0′ to 1° 32′ to every second; log sines, cosines, tangents and cotangents for every ten seconds from 0° to 6°, and for every minute to 45°: all to 7 places. When the intervals are 10″ or 1′, differences for a second are added: the logarithms are written at length. The table is followed by a page giving the circular measure of 1°, 2°,. . . . 10°, and thence by tens to 360°, of 1′, 2′,. . . . 60′, and of 1″, 2″,. . . . 60″, to 11 places.

T. III. Natural sines and tangents to every minute of the quadrant, to 7 places, with differences for 1″.

T. IV. Chord-table to radius 500, viz. lengths of semichords of arcs $\left(i.e. \sin\frac{x}{2}\right)$ from 0° to 125° at intervals of 5′, to 6 laces, for radius unity.

This table is followed by 2 pages of tables for the conversion of centesimals into sexagesimals &c.

T. V. All prime divisors of numbers to 102,000 (multiples of 2, 3, and 5 excluded), and primes from 102,000 to 400,313.

T. VI. Hyperbolic logarithms of numbers to 1000, and of primes from 1000 to 10,000, to 8 places. This is followed by powers of 2, 3, and 5 to the 45th, 36th, and 27th respectively.

T. VII. Powers of e and their logarithms, viz. e^x and $\log_{10}e^x$, from $x=\cdot01$ to $x=10$ at intervals of ·01, to 7 figures and 7 places respectively.

T. VIII. Square and cube roots of numbers to 10,000, to 12 and 7 places respectively. The table is followed by a page of coefficients, such as $\frac{1}{2\,.\,4}$ $\frac{1}{2\,.\,4\,.\,6}$, $\frac{1\,.\,3}{2\,.\,4\,.\,5}$, &c., to 10 places, and their logarithms to 7 places.

T. IX. Power-tables. A, the first 11 powers of numbers from ·01 to 1·00 at intervals of ·01, to 8 places. B, the first 9 powers of numbers from 1 to 100. C, squares and cubes from 1 to 1000. D, the first hundred powers of 1·01, 1·02, 1·025, 1·0275, 1·03, 1·0325, 1·035, 1·0375, 1·04, 1·045, 1·05, 1·06, to 6 places. E, the first hundred powers of the reciprocals of these numbers, to 7 places. F, the sums of the powers in D: this table therefore gives $x+x^2+\ldots.x^n$ $\left(=x\frac{1-x^n}{1-x}\right)$ for the values of x written down under D, and for $n=1, 2, 3, \ldots.$ 100. G stands in the same relation to E that F does to D. The tables from D to G were calculated for their use in computing interest &c.

T. XII. An extended table of Gaussian logarithms. It gives B from A= ·000 to A=2·000 at intervals of ·001, from A=2·00 to A=3·39 at intervals of ·01, and thence to A=5·0 at intervals of ·1, to 5 places. There are also given, besides, other quantities for the same arguments, viz. C (=A+B), D (=B+C), E (=A+C), and F (=B−A), all to 5 places, with differences and proportional parts (of two kinds) for B and C.

T. XIII. Interpolation table, viz. $\frac{x(x-1)}{2}, \ldots \frac{x(x-1)\ldots.(x-5)}{1\,.\,2\ldots6}$, from $x=\cdot01$ to $x=1\cdot00$ at intervals of ·01, to 7 places; then follows a page of constants. There are, besides, mortality tables, very complete tables of measures and weights of different countries, &c. The table of 12-place square roots was published[1] here for the first time: it was calculated by Hensel in 1804. The seven-place cube roots, the chord-table, and the new columns of the Gaussian table were calculated by Dr. Michaelis, of Leipzig. The author draws attention to the fact that the last figures in T. VIII. and XII. are given correctly.

It is a matter of sufficient interest to note here that, though the work is called an edition of VEGA, it contains one error from which the other tables known by the name of Vega and published subsequently to his folio of 1794 were free. In VLACQ (1628), log 52943 was printed 7238085868 instead of 7238085468, and the error was first pointed out and corrected by VEGA in his folio of 1794. All the seven-figure tables, therefore, from 1628 to 1794 (and several of the subsequent tables also), have 7238086 instead of 7238085; but VEGA's small editions (the 'Manuale' and 'Tabulæ') have the logarithms correctly printed. In HÜLSSE's edition, however, the error is reproduced afresh, and the last figure is printed 6. It follows therefore either that Hülsse did not reprint Vega's table, or that, if he did, he noticed the discrepancy, and decided in favour of the erroneous value. The slight suspicion thus cast on these tables is unfor-

tunate, as they form a most valuable collection, and are supplemental to CALLET. We have seen advertised a second edition (1849); and ZECH's tables (see ZECH, 1849, § 3, art. 19) are extracted from it. The last-figure error noticed above is the only one of the hereditary VLACQ's errors that appears in the table of the logarithms of numbers; so that but for this curious blunder the present work would have been, we believe, the first to be free from errors of this class (see 'Monthly Notices of the Roy. Ast. Soc.' March, 1873). Some remarks by Gauss on T. XII. appear in t. iii. pp. 255–257 of his 'Werke.'

Hutton, 1781 (products and powers of numbers). [T. I.] Products to 1000×100 (pp. 51).

[T. II.] Squares and cubes of numbers from 1 to 10,000 (pp. 54–78).

[T. III.] Squares of numbers from 10,000 to 25,400 (pp. 78–100).

[T. IV.] Table of the first ten powers of numbers from 1 to 100. Two errors (viz. the last three figures of 81^5 should be 401, not 101, and the last three of 98^7 should be 672, not 662) are pointed out by the reporter in the Philosophical Transactions, 1870, p. 370.

The remaining three pages of the book are devoted to weights and measures &c. The table is closely printed; and some of the pages contain a great many figures, as there are a hundred lines to the page. De Morgan states that the table has not the reputation of correctness; and the charge is no doubt true, as, besides the two errors noted above (both of which we found on the only page we have used), it is to be inferred from BARLOW's introduction to his tables that he found errors; he did not, however, publish any account of them.

Hutton, 1858. T. I. Seven-figure logarithms to 1000, and from 10,000 to 108,000, with proportional parts for *all* the differences. The change in the line is denoted by a bar placed over the fourth figure of all the logarithms affected.

T. II. Logarithms to 1000, and thence for odd numbers to 1199, to 20 places.

T. III. Logarithms from 101,000 to 101,149, to 20 places, with first, second, and third differences.

T. IV. Antilogarithms, viz. numbers to logarithms from ·00000 to ·00149 at intervals of ·00001, to 20 places, with first, second, and third differences.

T. V. Hyperbolic logarithms from 1·01 to 10·00 at intervals of ·01, and for $10^2 \ldots 10^5$, to seven places.

T. VI. Hyperbolic logarithms to 1200, to seven places.

T. VII. Logistic logarithms, viz. log $3600'' - \log x$, from $x = 1''$ to $x = 5280''$ ($= 88'$) at intervals of $1''$, to four places, the arguments being expressed in minutes and seconds.

T. VIII. Log sines and tangents to every second of the first two degrees, to seven places; no differences.

T. IX. Natural and log sines, tangents, secants, and versed sines for every minute of the quadrant, with differences, to seven places, semiquadrantally arranged. The natural functions occupy the left-hand pages, and the logarithmic the right-hand. In both these last two tables the logarithms are all written at full length.

T. XI. Circular arcs, viz. circular measure of $1°, 2°, \ldots 180°$, of $1', 2' \ldots 60'$, of $1'' \ldots 60''$, and of $1'''$ to $60'''$, to seven places.

T. XII. Proportional parts to hundredths of 2·302...., the reciprocal of the modulus.

Some constants are given in T. XX.; the other tables consist of a traverse table, formulæ, &c.

The edition described above is one of those edited by Olinthus Gregory, and is the last we have met with. The first edition was published in 1785, the second in 1794, the third in 1801, the fifth in 1811, and the sixth, the last published in Hutton's lifetime (he died 1823), in 1822.

We have compared the first, second, and sixth editions, and that of 1858 described above. The first two are nearly identical, so that we need only notice the differences between the tables of 1785, 1822, and 1858. In both the two former of these editions T. I. only extends to 100,000; and while in that of 1785 the change of figure in the line is not marked at all, in that of 1822 the fourth figure in the first logarithm affected only is marked. T. II. is the same in the 1822 edition, but it ends at 1161 instead of 1199 in that of 1785. T. III. in 1785 ended at 101,139, and is extended to 101,149 in both the other editions, as also did T. IV. originally end at ·00139. In the editions of 1785 and 1822 occur two tables that were left out by Gregory in 1830 and in succeeding editions, viz. T. 5, giving logarithms of all numbers to 100, and of primes from 100 to 1100, to 61 places, and T. 6, giving the logarithms of the numbers from 999,980 to 1,000,020, to 61 places, with first, second, third, and fourth differences. T. VI., of hyperbolic logarithms, appears in the edition of 1822, but not in that of 1785. T. VII. extended only to 80′ in 1785.

To all the first six editions is prefixed Hutton's introduction, containing a history of logarithms, the different ways in which they may be constructed, &c. This very valuable essay was omitted by Gregory in the seventh (1830) and subsequent editions (on account of its being rather out of place in a collection of tables), and with some reason. In the 1785 edition it occupied 180 pp., 55 pp. of which are the "Description and Use of the Tables." This portion Gregory retained; and in the 1858 edition it occupied 68 pp.

The whole work was reset in the later editions, published in Hutton's lifetime, the chief additions, as we infer from the preface, having been made in the fifth (1811) edition. On the last page of the 1822 edition are some errata found in CALLET (1783, 1795, and 1801), and also in TAYLOR (1792); the lists of errors in GARDINER (London and Avignon) are also more complete than in the earlier editions. HUTTON'S tables were the legitimate successors of SHERWIN'S, and bring down to the present time one of the main lines of descent from VLACQ (see SHERWIN, § 4).

Inman, 1871. [T. I.] Logistic logarithms, viz. $\log 3600^s - \log x$ from $x = 2$ to $x = 3600^s$ $(= 60^m)$ at intervals of 2^s, to 5 places. Arguments expressed in minutes and seconds.

[T. II.] Proportional logarithms, viz. $\log 10800'' - \log x$ to every second to 3° (same as T. 74 of RAPER, only to 5 places instead of 4), preceded by a page giving the same for every tenth of a second to 1′.

[T. III.] Log sines at intervals of 1″ to 50′, to 6 places.

[T. IV.] Log sines, tangents, and secants at intervals of 1^s to 3^h (arguments also given in arc, the intervals being 15″), to 6 places: the table is followed by a page of proportional parts for use with it.

[T. V.] $\frac{1}{2}$ log *haversines*, viz. $\frac{1}{2}$ log semi- versed sines $= \log \sin \frac{x}{2}$, from $x = 0°$ to 15° at intervals of 15″, thence to 60° at intervals of 30″, and thence to 180° at intervals of 1′, to 6 places (arguments also in time). *Note.*—In several instances in this table ′ is misprinted for ″.

[T. VI.] Log *haversines*. Same as previous table, except that 2 log sin

$\frac{x}{2}$ is the function tabulated; so that all the results are double those in [T. V.], and that the intervals are 15″ up to 135°, and then 1′ to 180°.

[T. VII.] Six-figure logarithms to 1000, and from 1000 to 10,000 in decades, with proportional parts.

[T. VIII.] Natural versed sines to every second (of time) to 36^m, to 6 places.

[T. IX.] Natural versed sines to every minute (of arc) to 180°, to 6 places, with complete proportional parts for every second up to 60″. The other tables are nautical.

The paging of the book runs at the top of the pages to 216, and thence at the bottom to 275; it then recommences at the top at p. 217. This is no doubt caused by [T. V., VI.] having been introduced in this edition only.

We have seen the original work, 'Nautical Tables designed for the use of British Seamen, by James Inman, D.D. London, 1830' (400 pp. of tables), but have not compared the two together: except for the "haversines," however, the tables seem to be nearly identical in the two editions.

Inman's 'Navigation and Nautical Astronomy' (2nd edit.), Portsea, 1826, contains no tables.

Irsengarth, 1810. These are merely land tables, and the units (Ruthe, Fuss, &c.) are so special that they do not appear to possess any mathematical value.

Jahn, 1837. Vol. I. Six-figure logarithms to 100,000; the change in the line is denoted by a dagger (†) prefixed to the fourth figure of all logarithms affected. There are no proportional parts on the page; but they are given in a separate table at the end.

Vol. II. Logarithmic sines and tangents for every second of the first degree; log sines and tangents for every third second of the quadrant (semiquadrantally arranged): all to 6 places. Proportional parts are given in the extreme right and left columns of the double page for every twentieth of the three-second interval.

The introductory matter is both in German and Latin.

We rather like the paper on which the second volume is printed; though not of a good quality, it is thick and stiff, and of a brownish colour, so that the book could be, we think, used for a long time at once without injury to the eye: the first volume (in the copy before us), however, is printed on paper of the soft, flaccid kind common in German books.

The author was led to publish his tables by observing that nearly all those in use were either five- or seven-figure tables.

We have seen, by the same author, 'Tafeln zur Berechnung für Kubik-Inhalt &c.,' 2nd edit., Leipzig, 1847; but the tables are commercial (arguments expressed in Zolle, Ellen, &c.), and do not need notice here.

Kerigan, 1821. T. VIII. Log sines for every second to 2°, and thence, at intervals of 5″, to 90°, to six places; in this latter part of the table proportional parts for seconds are added, so that the table practically gives log sines to every second; arranged quadrantally. The logarithms are all printed at length.

T. IX. Natural sines from 0° to 90° at intervals of 10″, to six places; no differences; the sines written at length.

T. X. Six-figure logarithms from 1000 to 10,000, with proportional parts; arranged as is usual in seven-figure tables; the change in the line is marked by the ciphers after the change in the third place being filled in, so as to render them black circles.

T. XI. *Logarithmic Rising*, viz. log versed sines from 0^h to 8^h at intervals of 5^s, with proportional parts to seconds, to 5 places: the logarithms are written at length.

T. XII. Proportional logarithms for every second to 3°, to four places; same as T. 74 of Raper.

T. XIII. Small table to convert arc into time: the other tables are nautical.

Köhler, 1832. [T. I.] Five-figure logarithms to 10,000, arranged consecutively in columns, with differences and characteristics; the degrees, minutes, &c. for every thirtieth number are added.

[T. II.] Log sines and tangents for every minute of the quadrant, to five places, with differences.

[T. III.] Gauss's table (§ 3, art. 19); viz. B and C are given for argument A from ·000 to 2·000 at intervals of ·001, thence to 3·40 at intervals of ·01, and to 5 at intervals of ·1, to five places, with differences.

There are besides a few constants; the introduction is in French and German.

Köhler, 1848. [T. I.] Seven-figure logarithms to 1000, and from 10,000 to 108,000 (this last 8000 being to 8 places), with differences and proportional parts; the change in the line is denoted by a bar placed over the fourth figure of all the logarithms affected. The constants S and T (§ 3, art. 13) and the variation are given at the top of the page, as also is the number of degrees, minutes, &c. corresponding to every tenth number. At the end are the first hundred multiples of the modulus and its reciprocal to 8 places, and a small table to convert arc into time.

[T. II.] Gaussian logarithms: B and C are given to 5 places (with differences) for A = ·000 to 2·000 at intervals of ·001, thence to 3·40 at intervals of ·01, and to 5·0 at intervals of ·1 (same as Gauss's table 1812, § 3, art 19).

[T. III.] Briggian logarithms of primes from 2 to 1811, to 11 places, followed by 2 pages of constants, some weights and measures, &c.

[T. IV.] Log sines, tangents, and arcs (all equal) for every second to 1′; and log sines, cosines, tangents, and cotangents for intervals of 10″ to 10°, and thence for intervals of 1′ to 45°, to 7 places, with differences for one second.

[T. V.] Circular measure of 1°, 2°.... 100°, 110°.... 300°, 330°, 360°, of 1′, 2′.... 60′, and of 1″, 2″.... 60″, to 11 places. Then follow some formulæ, and we come to the second part of the work, 'Mathematische Tafeln, die oft gebraucht werden,' containing:—

T. I. Hyperbolic logarithms (to 8 places) of numbers from 1 to 1000, and of primes from 1000 to 10,000.

T. II. The first 45, 36, and 27 powers of 2, 3, and 5 respectively.

T. III. e^x from x=·01 to 10·00 at intervals of ·01 to 7 figures.

T. IV. The first ten powers of numbers from 1 to 100.

T. V. Squares of numbers from 1 to 1000.

T. VI. Cubes of numbers from 1 to 1000.

T. VII. Square and cube roots (to 7 places) of all numbers from 1 to 1000.

T. VIII. Factor tables, giving all divisors of all numbers not prime or divisible by 2, 3, or 5, from unity to 21,524.

T. IX. To express minutes and seconds as decimals of a degree &c.

T. X. Binomial-theorem coefficients, viz. x, $\frac{x(x-1)}{1.2}$, &c.... $\frac{x...(x-4)}{1.2.3.4}$, from x=·01 to 1·00 at intervals of ·01, to 6 places.

T. XI. Decimal values of certain coefficients, such as $\frac{1.3.5}{2.4.6.7}$, $\frac{1}{2.4.5}$, $\frac{3}{2.6.7}$, &c., with their logarithms. There are 40 in all; and the table occupies one page.

A reward of a louis d'or was offered for every error found in the first edition; all the errors so found are corrected in the second, here described.

Lalande, 1805. [T. I.] Five-figure logarithms of numbers from 1 to 10,000, arranged consecutively in columns, with differences.

[T. II.] Log sines and tangents for every minute of the quadrant, to 5 places. An explanation of 34 pp. is prefixed.

Lalande, 1829. [T. I.] Seven-figure logarithms to 10,000, arranged in columns with characteristics and differences; the number of degrees, minutes, &c. for the first number in each column (viz. for every thirtieth number) is given at the top.

[T. II.] Log sines and tangents for every minute of the quadrant, to 7 places, with differences.

Lambert, 1798. T. I. Divisors of all numbers up to 102,000 not divisible by 2, 3, or 5. If the number is the product of only two prime factors, then the least only is given; but if of more than two, the others are given, except the largest. The table therefore gives all the simple factors except the greatest. The letters f, g, h, &c. are used for 11, 13, 17, &c. (as explained on p. xviii of the introduction), not only because they occupy less room, but also because they can be placed in contact without risk of mistake; the least factor, however, is always written at length.

T. II. *Abacus numerorum primorum,* viz. first 10 multiples of all the primes up to 313.

T. III. Seven products, each of seven consecutive primes, from 7 to 173.

T. IV. List of the three-figure endings that squares of odd numbers admit of.

T. VI. Primes from 1 to 101,977.

T. VII.–IX. Powers of 2 to 2^{70}, of 3 to 3^{50}, of 5 to 5^{30}.

T. XI. e^{-x} (to 7 places) for $x = \cdot 1, \cdot 2, \ldots \cdot 9, 1, 2, \ldots 10$.

T. XIII. & XV. Hyperbolic logarithms (to 7 places) of numbers from 1 to 100, and from 1·01 to 10·00 at intervals of ·01, respectively.

T. XIV. & XVI. contain $\log_e 10, 10^2 \ldots 10^{10}$, to 7 places, and $\log_e 2, 3 \ldots 10$, and $\frac{1}{\log_e 10}$, to 25 places.

T. XVII. Tables of numbers of the form $2^n. 3^n. 5^p. 7^q$ arranged in order up to 11,200.

T. XXIII. Circular measure of 1°, 2°...100°, 120°, 150°, 180°...360°, of 1′, 2′...10′, 20′...60′, and of 1″, 2″...10″, 20″...60″, to 27 places.

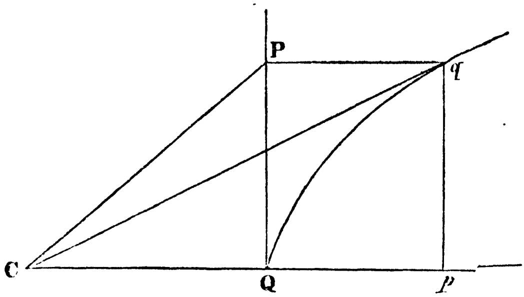
T. XXIV. $\phi = 10000''m$; $\phi, \phi^2 \ldots \phi^{10}$ expressed in terms of m (in circular measure), to 16 places, and $\sin\phi$, $\cos\phi$ expressed in terms of m with decimal coefficients, to 18 places. Also π, $\log\pi$, $\frac{1}{\pi}$, $\sqrt{\pi}$, &c. to a good many places.

T. XXV. Natural sines to every degree and their first 9 multiples, to 5 places.

T. XXVI. Sines, tangents, and secants, and log sines and tangents to every degree, to 7 places.

T. XXIX. Table for facilitating the solution of cubic equations, viz. $a = \pm(x - x^3)$ from $x = \cdot 001$ to $1\cdot 155$ at intervals of ·001, to 7 places.

T. XXXII. *Functiones hyperbolicæ circularibus analogæ.* Q q being a rectangular hyperbola, centre C, P C Q is the so-called *angulus transcenden* $= \phi$ say, q C Q the *angulus communis* $= \psi$ say; $p\ q$ is the hyperbolic sin C p the hyperbolic cosine, and C q Q the *sector*; so that if the hyperbola $x^2 - y^2 = 1$, $x = \sec \phi$ and $y = \tan \phi$.



The argument is ϕ, and proceeds from 0° to 90° at intervals of 1°; and the table gives the sector, y, x, log y, log x, tan ψ, log tan ψ and ψ, all except the last to 7 places, and the last to one decimal of a second.

T. XXXV. & XXXVI. Squares and cubes of numbers from 1 to 1000.

T. XXXVII. Figurate numbers (first 12 series), viz. x, $\frac{x(x+1)}{1.2}$, $\frac{x(x+1)(x+2)}{1.2.3}, \ldots \frac{x(x+1)\ldots(x+11)}{1.2.3\ldots12}$ from $x=1$ to 30.

T. XL. First 11 powers of ·01, ·02, ·03. . .1·00, to 8 places.

T. XLIV. Coefficients of the first 16 terms in $(1+x)^{\frac{1}{2}}$ and $(1+x)^{-\frac{1}{2}}$, their accurate values being given as decimals.

Besides the above, T. XIX. gives sin 3°, 6°. . .89° in radicals, and T. XLII. the first 6 or 9 convergents to $\sqrt{2}$, $\sqrt{3}$, $\sqrt{5} \ldots \sqrt{12}$ as vulgar fractions. The other tables contain formulæ &c.

The work is edited by Felkel, who has prefixed a *Præfatio Interpretis* of xi pp., giving a description of his (Felkel's) tables of divisors &c.; and there is also added at the end an account of his proposed scheme of tables in relation to the theory of numbers. About Felkel, see FELKEL, 1776, § 3, art. 8.

The titlepage states that this is a translation from a German edition. The original was entitled "Zusätze zu den logarithmischen und trigonometrischen Tabellen," and was published in 1770; or, at all events, De Morgan's description of the contents of this latter work, which we have not seen, agrees, as far as it goes, almost entirely with the 'Supplementa' &c., which De Morgan had heard of, but not seen. The introduction to the latter shows signs of having been amplified by Felkel.

Lax, 1821. T. XIV. Proportional logarithms, viz. log 10800″ − log x from $x=0''$ to $x=10800''$ ($=3°$) at intervals of 1″ (the arguments being expressed in degrees, minutes, and seconds), to five places. On the first page, however, which extends to 10′, only two, three, or four places are given correctly, the number being filled up to five by adding ciphers; facing 0° 0′ 0″ there is given 4·88. . instead of $-\infty$.

T. XVII. Natural versed, suversed, coversed, and sucoversed sines, viz. $1-\cos x$ and $1+\cos x$ for every minute of the quadrant, to six places, with proportional parts for 1″, 2″. . . 60″, so that the tabular results can be taken out very easily to seconds. It may be observed that of the double columns

headed ′ and ″ the first refers to the argument and the second to the proportional parts. This table occupies pp. 57–80 of the book.

T. XVIII. Six-figure logarithms to 15,500, with proportional parts at the foot of the page to twentieths for the portion beyond 1000. The table is so arranged that all the logarithms are given at full length, though this is not the case with the numbers; for example, to find the logarithm of 15184 we seek 15150 at the head of the column, and line 34 in the column: this defect might have been partially remedied by the introduction of another column at the right-hand side of the page containing the numbers 50, 51 . . . 99. The other tables, 22 in number, are nautical.

Lynn, 1827. T. Z. (pp. 244–283). A sexagesimal proportional table, exhibiting at sight, in minutes, seconds, and tenths of a second, the fourth term in any proportion in which the first term is 60 minutes, the second term any number of minutes under 60 minutes, and the third term any number of minutes and seconds under 10 minutes. If the second term is not an exact number of minutes the table can still be used, though two operations are required. The table may be described as giving $\frac{xy}{60}$, in minutes, seconds, &c., x (running down the column) being $1'$, $2'$ . . . $60'$, and y (running along the top lines) extending to $10'$ at intervals of $1''$.

T. E. (pp. 288, 289). Proportional logarithms for every minute to 24^h, viz. $\log 1440^m - \log x$, from $x=1^m$ to $x=1860^m$ ($=31^h$) at intervals of unity, the arguments being expressed in hours (or degrees) and minutes, to four places; the other tables are nautical.

Mackay, 1810 (vol. ii.). T. XLI. Natural versed sines for every ten seconds to 180°, to six places.

T. XLV. Six-figure logarithms of numbers to 100, and from 1000 to 10,000, with differences; the logarithms written at length.

T. XLVI. Log sines to every ten seconds of the quadrant, to six places.

T. XLVII. Log tangents to every ten seconds of the quadrant, to six places.

T. XLVIII.–L. *To find the latitude by double altitudes of the sun or stars and the elapsed time.* The first and second of these tables give log cosec x and log ($2 \sin x$) from $x=0^h$ to $x=3^h\ 59^m\ 50^s$ at intervals of 10^s; and the third gives log versed sines to $7^h\ 59^m\ 50^s$ at intervals of 10^s, all to five places, the logarithms being written at length. These tables were copied, according to the author (see note, vol. ii. p. 31), from the second edition (1801) of this work without acknowledgment into Norie's 'Epitome of Navigation.'

T. LI. Proportional logarithms to every second to 3°, to four places; same as T. 74 of Raper; the other tables are nautical.

The table of natural versed sines was calculated for this work, and appeared in the first edition (1793); it has since, the author states, been frequently copied (see note, vol. ii. p. 13).

Maseres, 1795. This is a collection of reprints of tracts, and, among others, of "An Appendix to the English Translation of Rhonius's German Treatise of Algebra, made by Mr. Thomas Brancker, M.A., . . . At London, in the year 1668 . . . . ." And on pp. 367–416 is given "Thomas Brancker's Table of Incomposit or prime Numbers, less than 100,000," viz. least factors of all numbers up to 100,000 not divisible by 2 or 5. On p. 366 is a rather long list of errors in the table (we suppose Maseres reprinted verbatim from his copy, as some of the errata are corrected and some are not), and also some errors in Guldinus, Schooten, and Rhonius. The table is preceded (pp. 364, 365) by 'A Tarriffa, or Table, of all Incomposit or prime numbers less than $\sqrt{100{,}000}$, multiplied by 2, 3, 4, 5, 6, 7, 8, 9."

On pp. 591, 592, T. XIX. of DODSON's 'Calculator,' 1747 (viz. square and cube roots of numbers less than 180, to 6 places), is reprinted; and on pp. 595–604 are reciprocals (to 9 places) and square roots (to 10 places) of numbers from 1 to 1000, reprinted (as Maseres states in the preface) from vol. iv. of Hutton's 'Miscellanea Mathematica' (1775, 4 vols. 12mo).

Maskelyne (Requisite Tables), 1802. T. XV. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of RAPER.

T. XVI. *For computing the latitude of a ship at sea*, &c. The arguments run from 0^h to 6^h at intervals of 10^s; and there are three columns of tabular results headed Log ½ Elap. time, Log Mid. time, Log rising, which give respectively log cosec x, log (2 sin x), and log vers sin x, to 5 places; the *log rising* is also continued for arguments from 6^h to 9^h at the same intervals. This table, modified in form &c., is reproduced in MACKAY, DOMKE, &c. (see § 3, art. 15, p. 68, and BOWDITCH, 1802), and is sometimes called by Maskelyne's name.

T. XVII. Natural sines to every minute of the quadrant, to 5 places.

T. XVIII. Five-figure logarithms of numbers to 10,000.

T. XIX. Log sines, secants, and tangents to every minute of the quadrant, to 5 places; the sines are given to 6 places, the last being separated from the rest by a point; the other tables are nautical.

Maskelyne's name does not appear on the titlepage to these tables; but the preface is signed by him.

APPENDIX TO THE THIRD EDITION. T. I. Natural sines to every minute of the quadrant, with proportional parts for seconds.

T. II. Natural versed sines for every minute to 120°, with proportional parts for seconds.

T. III. Logarithms of numbers to 1000, arranged consecutively, and printed in groups of five; and thence to 100,000 grouped in decades, with proportional parts for each decade by its side. All the tables in the Appendix are to six places. Copies of the Appendix were circulated separately.

Minsinger, 1845. [T. I.] Seven-figure logarithms to 100 and from 1000 to 10,000, with proportional parts at the foot of the page; the sixth place is separated by a comma from the seventh, for convenience if the table is to be used to six places. The change in the line is denoted by an asterisk attached to all the logarithms affected.

[T. II.] Squares, cubes, and square and cube roots (to 6 places) of all numbers from 1 to 100, and squares and cubes only of numbers from 100 to 1000. Then follow a few constants and [T. IV.] primes to 1000.

Moore, Sir Jonas, 1681. [T. I.] Seven-figure logarithms to 10,000 (arranged as is now usual), with differences: the proportional parts [T. II.] are given by themselves at the end, and occupy 22 pp. This may be regarded as a separate table, containing proportional parts (to tenths) of numbers from 44 to 4320—the interval being 2 to 900, 3 to 999, 4 to 1415, 5 to 2000, and 10 to 4320.

[T. III.] Natural and log sines, tangents, and secants to every minute of the quadrant, to 7 places (semiquadrantally arranged), without differences. It may be remarked that many of the N's at the top of the columns are imperfectly printed, and appear like V's; thus N. tangent is often printed V. tangent.

[T. IV.] (pp. 262–351). Natural and log versed sines from 0° to 90° to every minute, to 7 places. De Morgan says that this is the first appearance of this table in England. The other tables relate to navigation, geography, &c.

[**Moore, Sir Jonas,** 1681] (Versed sines). Natural and log versed sines to every minute of the quadrant, to 7 places, semiquadrantally arranged.

The copy of this tract before us (which is bound up in a volume with several others, and belongs to the Cambridge University Library) is clearly either a separate reprint or merely a table torn out from some larger work. The paging runs from 262 to 351 : at the beginning there is a plate, the size of the page, of a person observing with a sextant, and the words "between page 248 and 249" below in the left hand-corner, and at the end a diagram with a movable circle and pointer, headed "The fore part of the Nocturnall or side held next the face in time of observation," and "between page 254 and 255" below. On examination we find the table is [T. IV.] of Sir JONAS MOORE'S 'Systeme of the Mathematicks,' 1681, just described. The engravings do not, however, appear to be taken from either volume of this work. It is very likely that this table was merely torn out from the work, and was never published separately; still as, according to De Morgan, this is the first appearance of such a table in England, it is not improbable that copies may have been in request, and therefore issued separately.

J. H. Moore, 1814. T. III. Log sines, tangents, and secants to every quarter-point, to 5 places.

T. IV. Five-figure logarithms of numbers to 10,000.

T. V. Log sines, tangents, and secants for every minute of the quadrant, to 5 places.

T. XXIII. Log $\frac{1}{2}$ elapsed time, mid. time, and rising (for explanation of these terms see T. XVI. of MASKELYNE, § 4) for every 10^s to 6^h, except the last, which is to 9^h, to 5 places. The tables are separated as in MACKAY.

T. XXIV. Natural sines for every minute of the quadrant, to 5 places.

T. XXV. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of RAPER.

We have seen the 18th edition (1810), which is identical with that above described, an edition of 1793, and the 9th edition (1791) (the last two not edited by Dessiou). All contain the tables described in this account (though the order is different), except that the tables in T. XXIII. are not separated; the log rising is only given to 6^h, and the intervals also 30^s, in the two earlier editions.

Three out of the four editions contain different portraits of the author.

Müller, 1844. [T. I.] Five-figure logarithms of numbers from 1000 to 1500, and four-figure logarithms from 100 to 1000.

[T. II.] Table of Gaussian logarithms in a somewhat modified form, viz. S and U to 4 places, from A=·0000 to ·0300 at intervals of ·0001, thence to ·230 at intervals of ·001, and from ·20 to 2·00 at intervals of ·01, and thence to 4·0 at intervals of ·1, with differences; where

$$A = \log x,\quad S = \log\left(1+\frac{1}{x}\right),\quad \text{and } U = \log\frac{1}{1-\frac{1}{x}}.$$

[T. III.] Squares of numbers from 0 to 1 at intervals of ·0001, to 4 places, and quarter squares of numbers from 0 to 2 at the same intervals, also to 4 places (intended for use in the method of least squares).

[T. IV.] Four-place log sines and tangents for every second to 10′, thence at intervals of 10″ to 1°, thence at intervals of 1′ to 4°, and to 90° at intervals of 10′.

There are given also:—the circular measure (to 12 places) of 1°, 2° ... 10°, 1′ ... 10′ and 1″ ... 10″; 12 constants involving π; natural sines and tangents to every half degree; and a few three-figure logarithms.

John Newton, 1658. [T. I.] Logarithms to 1000, to 8 places, and logarithms from 10,000 to 100,000, also to 8 places. A column is added to each page containing the logarithms of the differences, to 5 places.

[T. II.] Log sines and tangents (semiquadrantally arranged) for every centesimal minute (viz. nine-thousandth part of a right angle), to 8 places, with differences.

[T. III.] Log sines and tangents for the first three degrees of the quadrant, to 5 places, the interval being the one thousandth part of a degree. Logarithms of the differences to 8 places are added.

The trigonometrical tables are thus of the kind introduced by BRIGGS, and are partly centesimal (see § 3, art. 15, p. 64). This is the only extensive eight-figure table that has been published; and it is also remarkable on account of the logarithms of the differences, instead of the differences, being given. It seems worth consideration whether, in the event of a republication of VLACQ, 1628, it would not be advantageous to replace the differences by their logarithms. It is usually most convenient, if many logarithms are to be taken out at one time, to interpolate for the last five figures in a ten-figure table by means of an ordinary seven-figure table; but in other cases recourse is generally had to simple division, and the natural differences are best. The table would occupy too much space if both the differences and their logarithms were added; and there is not much chance of two publications ever being made, one with natural, and the other with logarithmic, differences. If the choice had to be made, the decision would probably be in favour of the simple differences as they are, though a good deal might be urged on the other side.

A few errata are given at the end of the address to the reader, and a great many more on the last page; the tables, however, reproduce nearly all VLACQ's errors, which affect the first 8 places (see 'Monthly Notices of the Roy. Ast. Soc.' March 1873). This was the first table in which the arrangement, now universal in seven-figure tables (viz. with the fifth figures running horizontally along the top line of the page), was used. The change of the third figure in the line is not noted.

The title of this work being the 'Trigonometria Britannica' (printed 'Britanica' on the titlepage), it is often confounded with BRIGGS's work of this name, Gouda, 1633 (§ 3, art. 15), from which it is derived. Also, as Gellibrand's name appears on the titlepage it is sometimes attributed to him in catalogues.

In the Cambridge University Library is a copy of this book, in which the titlepage and introduction are absent, the first page being the titlepage to the tables, so that the work is anonymous. Whether some copies of the tables alone were published, or whether the copy in question is imperfect, we do not know.

Norie, 1836. T. XXIII. Log sines, tangents, and secants to every quarter-point, to 7 places.

T. XXIV. Six-figure logarithms of numbers to 10,000, with differences.

T. XXV. Log sines and tangents to every ten seconds to 2°, and log sines, tangents, and secants for every minute of the quadrant, to 6 places, with differences.

T. XXVI. Natural sines for every minute of the quadrant, to 6 places.

T. XXVII.–XXIX. *To find the latitude by double altitudes and the elapsed time.* Log ½ elap. time, middle time, and rising (for explanation of these terms see T. XVI. of MASKELYNE, § 4) are given at intervals of 5^s, the two former to 6^h, and the last to 9^h, to 5 places, with proportional

parts. The three tables are separated, as is now usual (see MACKAY, § 4, T. XLVIII.).

T. XXXI. *Logarithms for finding the apparent time or horary angle*, viz. $\log \frac{1-\cos x}{2} \left(= 2 \log \sin \frac{x}{2}\right)$ from $x = 0^h$ to $x = 9^h$ at intervals of 5^s, to 5 places, with proportional parts for seconds.

T. XXXIV. Proportional logarithms for every second to 3°; same as T. 74 of RAPER.

T. XXXVI. Natural versed sines to every minute of the quadrant, with proportional parts for every second of the minute-interval, to 6 places.

The other tables are nautical. These tables also appear in NORIE's 'Epitome of Navigation.'

Norie (Epitome), 1844. The tables are the same as in NORIE's Nautical Tables just described; they are added after the explanatory portion, which occupies 328 pp.

On the different editions, see NORIE's Epitome in § 5.

Norwood, 1631. Seven-figure logarithms to 10,000, and log sines and tangents to every minute, to 7 places, semiquadrantally arranged: of the latter we have seen separate copies under the title, "A triangular canon logarithmicall" (the title it has also in the work). The editions we have seen are:—first, 1631; second, 1641; third, 1656; seventh, 1678.

This was one of the first small tables in which the trigonometrical canon was derived from VLACQ, 1628, and not GUNTER, 1620.

Oppolzer, 1866. Four-figure logarithms, with proportional parts to 1000. A page of Gaussian logarithms, after FILIPOWSKI, and a page of proportional parts. Log sines, cosines, tangents, cotangents to 10° at intervals of 1′, with differences, and from 10° to 45° at intervals of 10′, with differences and proportional parts, all to 4 places.

Oughtred, 1657. [T. I.] Sines, tangents, and secants (to 7 places) and log sines and tangents (to 6 places) for every *centesimal* minute ($= \frac{1}{9000}$ of a right angle) of the quadrant. Sines, tangents, and secants on the left-hand page of the opening, and cosines, cotangents, and cosecants, &c. (though not so called or denoted) on the right-hand page.

[T. II.] Seven-figure logarithms of numbers from 1 to 10,000, followed by a 'Tabula differentiarum' for the sines and tangents.

In an appendix at the end of the book it is explained that the logarithmic sines and tangents were intended by the author to consist of seven figures after the index, but that "the seventh figure was unhappily left out." This is also referred to in the dedication.

Ozanam, 1685. Natural sines, tangents, and secants, and log sines and tangents, and logarithms of numbers to 10,000, all to 7 places. There are 120 pp. of trigonometry &c. De Morgan points out that the tables are really Vlacq's, though his name is not mentioned, and takes occasion very truly to remark how many authors have considered that the merit of their books consisted in the trigonometry, and that the tables (which usually form by far the greater part of the work) were accessories of which no notice need be taken.

Parkhurst, 1871. This little book contains forty-two tables, with the last two of which this Report is not concerned. In describing briefly their contents, it will be convenient to mention first the tables which contain results most common in other works, such as logarithms &c., viz.:—

T. II., III., and IX. Logarithms from 1 to 109, to 102 places.

T. V. Multiples of the modulus ·43429... from 10 to 96, to 35 places.

T. XII. Logarithms of numbers from 1000 to 2199 at intervals of unity,

from 2200 to 2998 at intervals of 2, from 3000 to 4995 at intervals of 5; all to 10 places (from VLACQ).

T. XIII. Logarithms of numbers from 200 to 1199, to 20 places (from CALLET).

T. XIV. (continuation of T. XIII.). Logarithms of numbers from 1200 to 1399 at intervals of unity, from 1400 to 2998 at intervals of 2, from 3005 to 4995 at intervals of 10; all to 20 places.

T. XVIII. Logarithms of primes from 113 to 1129, to 61 places (from CALLET).

T. XX., XXI., XXII. A table of least divisors of numbers to 10,190, and, for certain divisors, to 100,000. Multiples of 2, 3, 5, 7, and 11 are excluded; it is very inconveniently arranged, and is moreover imperfect.

T. XXIII. Primes to 12,239.

T. XXV. Reciprocals from 300 to 3299, to 7 places, arranged like an ordinary table of seven-figure logarithms.

T. XXVI. Products of the numbers from 200 to 399 by the digits 1, 2 . . . 9, and squares from 200^2 to 399^2.

T. XXVII., XXVIII. A few logarithms and antilogarithms, to 3 places, and a similar small table to 4 places.

T. XXX., XXXI. Natural and log sines and tangents &c., to 4 places.

T. XXXII. Binomial-theorem coefficients (the first six for indices from unity to 40), and squares from 1^2 to 200^2.

T. XXXIII., XXXIV. Multiplication table from 16×13 to 99×98, and multiplication table of squares from $16^2 \times 13$ to $99^2 \times 98$.

T. XXXV., XXXVII., XXXVIII. Antilogarithms, logarithms to 8 places, and log sines.

The other tables are:—

T. IV. Logarithms of factors, 102 decimals. T. VI. Secondary multiples. T. VII. Factors to 3 decimals. T. VIII. Logarithms of factors, 31 decimals. T. X. Factors to 61 decimals. T. XI. Log F, for logarithms to 10 decimals. T. XV., XVI., XVII. Logarithms to 20 decimals of factors. T. XIX. Constants derived from the modulus. T. XXIV. Log ρ, for addition and subtraction. T. XXIX. Subtraction logarithms. T. XXXVI. Factors. T. XXXIX., XL. Interpolations, Bessel's coefficients.

Most of these tables are tabulated for their use in the calculation of logarithms by well-known methods. The arrangement of the work is most confused; and it would be very difficult to understand from the author's description the objects of his tables. The paging of the book runs from 1 to 176; and this portion includes all the tables. Then Part 2 commences, and the pages are numbered afresh from 1 to 38. In Part 3 the pages proceed from 1 to 27. Parts 2 and 3 are occupied with a description of the tables; and the reader who wishes to understand the meaning of the notation (which is often needlessly complex and confusing, to save the space of a few figures), &c., is recommended to begin at Part 3, p. 5. It would take too much room, even if it were worth while, to explain the tables in detail; but it may be stated that the tables (for the construction of logarithms of factors) give the values of $\log\left(1+\frac{m}{10^n}\right)$ and $\log\left(1-\frac{m}{10^n}\right)$ for different values of m and n to a great many places, as required in Weddle's and similar methods.

It will save the reader some trouble to mention that by $n\,\big)\!\circ m$ in the book is meant $\log\left(1+\frac{m}{10^n}\right)$, and by $-n\,\big)\!\circ m$, $-\log\left(1-\frac{m}{10^n}\right)$. Generally

the m is left out, where it is thought the context prevents risk of mistake; and instead of $-n$ ⁾ m there is sometimes written n ⁾ m, and the heading "cologarithm." The last page of the book, headed (wrongly) Table XXXIII., contains a very imperfect list of the abbreviations used.

It is to be inferred from the Preface &c., that the book was set up and lectrotyped by the author himself, who states that "it is probable that there not now a single error in the whole table." The reward of a copy of the book lso offered to the first finder of any important error under certain condi-ba . Parts of the book, in the copy before us, are very badly printed, so cro in fact that one or two pages are wholly illegible; and the tables are so othel that we should think no one would use them who could procure any have at could be made to do as well. In fact the author's object seems to smallesto crowd the greatest possible amount of tabular matter into the in the core, without any regard to clearness. It is stated in the work that illegible) of the printing, incomplete copies (some containing proofs almost cover states istributed to the author's friends; and an advertisement on the at different pr copies containing proofs rejected in the printing may be had The book is pr according to their completeness and the order of the tables. most confused, b phonetically; and this adds to the awkwardness of the with in the prepa printed, and ill-explained series of tables we have met and manner he has of this Report. By issuing his tables in the form several are the resuied, the author has not done justice to himself, as elsewhere. original calculation and are not to be met with

Pasquich, 1817.

consecutively in columns). Five-figure logarithms to 10,000 (arranged

T. II. Log sines, cosines out differences.

tervals of 10″, thence to 1° ecants, and cotangents, from 0′ to 56′ at in-of 1′, with differences for 1″. rvals of 20″, and thence to 45° at intervals and cotangents from 1° to 45° squares of natural sines, cosines, tangents, says, "This trigonometrical ca ervals of 1′, all to 5 places. De Morgan

T. III. Gaussian logarithms. squares is, we suppose, almost unique." places, with differences, for argu C (same notation as in Gauss), to 5 intervals of ·001, from A = 2·0 to A, from A = ·000 to A = 2·000 at A = 3·4 to A = 5 at intervals of ·1 Th ·40 at intervals of ·01, and from given by Gauss, 1812 (§ 3, art. 1 ble is the same as that originally

A few constants &c. are added in App.

A lengthy review of this work Gauss dix.

gelehrte Anzeigen' for Oct. 4, 181 It is peared in the 'Göttingische t. iii. of his 'Werke.' rinted on pp. 246–250 of

Pearson, 1824. Vol. I. contains large qua pages of tables; but only three pages come within the range his Report, viz.:—[T. I.], p. 109, a one-page table to convert space into ti and vice versâ. [T. II.], p. 261, which expresses 1°, 2°, 3°. . . . 360°, and 6′ as decimals of the cir-cumference of the circle to 4 and 5 places respectively and [T. III.], p. 262, which gives the circular measure of 1°, 2° 180°, o. 1′, 2′. . . . 60′ and of 1″, 2″. . . . 60″, to 8 places.

The other tables are nautical, astronomica.

Peters, 1871. [T. I.] pp. 16, 17. Hun is, thousandths, ten-thou-sandths, hundred-thousandths and millionths day expressed in minutes and seconds.

[T. II.] pp. 18, 19. For the conversion of ar time, and vice versâ.

[T. III.] pp. 20, 21. Lengths of circular arcs, viz. 1°, 2°, 3°....90°, thence to 115° at intervals of 5°, and to 360° at intervals of 10°, 1′, 2′....60′, and 1″, 2″....60″, expressed in circular measure, to 7 places.

[T. IV.]. Interpolation tables. Table I. (p. 103) gives $\frac{x(x-1)}{4}$, $\frac{x(x-1)(x-\frac{1}{2})}{6}$ and $\frac{(x+1)x(x-1)(x-2)}{48}$ from $x=\cdot00$ to $x=1\cdot00$ at intervals of ·01—the first function to 5 places (with differences), and the second and third to 4 places (without differences). It will be noticed that on writing $1-x$ for x, the first and third functions are unaltered, while only a change of sign is produced in the second. It is thus sufficient to tabulate them only from 0 to ·50, and to write the arguments down the column from 0·00 to ·50, and upwards from ·50 to 1·00, attending to the sign of the second function; and this is accordingly the arrangement in the table. Table I[illegible] (pp. 104, 105) contains $\frac{x^2}{2}$, $\frac{x^2(x^2-1)}{12}$, $\frac{x^2(x^2-1)}{24}$, and $\frac{x(x^2-1)(x^2-4)}{240}$ from $x=0\cdot00$ to $x=1\cdot00$ at intervals of ·01, the first to 5 and [illegible] others to 4 places. The first two have differences added. [illegible] cants th[illegible] ghout

[T. V.] (pp. 106–150). Natural sines, tangents, and [illegible] nces. the quadrant to every minute, to 5 places, without di[illegible] [illegible] rrang[illegible]

[T. VI.] (pp. 151–169). Table of squares to 10[illegible] [illegible] d as in a table of logarithms, the last figures of the squares [illegible] st be 0, 1, 4, 5, 6 or 9) being printed once for all at the bottom of [illegible] umns.

The other tables are either astronomical or meteor[illegible] al. There are 13 pp. of formulæ.

Rankine, 1866. T. I. Squares, cubes, reciprocals (to 9 places) and five-figure logarithms of numbers from 100 to 100[illegible].

T. 1 A. Square and cube roots (to 7 places), and reciprocals (to 9 places) of primes from 2 to 97.

T. 2. Squares and fifth powers of numbers from 10 to 99.

T. 2 A. Prime factors of numbers [illegible]

T. 3. Hyperbolic logarithms of [illegible] 100, to 5 places.

T. 3 A. Ten multiples of the m[illegible]on of [illegible] its reciprocal.

T. 4. Multipliers for the con[illegible]al, squ[illegible] [illegible]cular lengths and areas, viz. a few multiples of π and its reci[illegible] roots, &c.

T. 5. Circumferences and [illegible]s of cir[illegible]cles, viz. πd (to 2 places), and $\frac{\pi d^2}{4}$ (to the nearest integer), fr[illegible] $d=101$ [illegible] o $d=1000$.

T. 6. Arcs, sines, and [illegible]gents for every degree, to 5 places.

Raper, 1846. T. [illegible] Six-figure logarithms of numbers from 1 to 100 and from 1000 to 10,000 with proportional parts at the foot of the page.

T. II. Log sines for every second from 0° to 1° 30′, to five places.

T. III. Log sines fo[illegible] every te[illegible] seconds from 1° 30′ to 4° 31′, to 6 places, with proportional parts.

T. IV. Log sines, tangents, a[illegible]d secants for every half minute of the quadrant, to 6 places, with proportional parts.

T. V. A page of constants.

Raper, 1857. T. 21 A. *Logarithms for reducing daily variations*, viz. log 1440^m − log x, from $x=1^m$ to $x=1440^m$ (= 24^h) at intervals of a minute, to 4 places, the arguments being expressed in hours and minutes.

T. 64. Six-figure logarithms of numbers to 100, and from 1000 to 10,000, arranged as in usual in seven-figure tables, except that the logarithms are

printed at full length; the proportional parts are given at the foot of the page.

T. 65. Log sines, tangents, and secants to every quarter point, to six places.

T. 66. Log sines of small arcs, viz. for each second to 1° 30′, thence (T. 67) for every ten seconds to 4° 31′, to 6 places, the logarithms being printed at length; T. 67 has proportional parts.

T. 68. Log sines, tangents, and secants (printed at full length) for every half minute of the quadrant, to 6 places, with differences and proportional parts for 1″, 2″....30″ (= half a minute) beyond 3°, semiquadrantally arranged; arguments also expressed in time.

T. 69. Log $\sin^2 \frac{x}{2}$ from $x = 0$ to $x = 180°$ at intervals of 15″ (arguments expressed also in time), to 6 places; all the logarithms printed at full length: no differences.

T. 74. Proportional logarithms, viz. log 10800″ − log x from $x = 1$ to $x = 10800''$ ($= 3°$ or 3^h) to every second, the arguments being expressed in degrees (or hours), minutes, and seconds, to 4 places; the other tables are nautical &c.

Reynaud, 1818. The trigonometry occupies 182 pages; and after the diagrams are inserted LALANDE's logarithms, which are quite disconnected from the work.

[T. I.] Five-figure logarithms to 10,000, arranged in columns, with characteristics and differences; the number of degrees, minutes, &c. for the first number in each column (viz. for every thirtieth number) is given at the top.

[T. II.] Log sines and tangents for every minute of the quadrant, to 5 places, with differences.

Riddle, 1824. T. IV. Log sines, tangents, and secants to every point and quarter point of the compass, to 6 places.

T. V. Six-figure logarithms of numbers to 100, and from 1000 to 10,000, with differences, arranged as usual.

T. VI. Log sines, tangents, and secants to every minute of the quadrant, to 6 places, with differences, semiquadrantally arranged. [The heading of this table in the book is inaccurate.]

T. XXVIII. Natural versed and suversed sines, viz. $1 - \cos x$ and $1 + \cos x$, for every minute of the quadrant, to 6 places, with proportional parts for 1″, 2″...60″, so that the tabular results can be taken out very easily to seconds. The extreme left- and right-hand columns serve both for minutes in the arguments and for multiples in the proportional parts. The first figure of the versed sine and the first two of the suversed sine are generally omitted throughout.

T. XXIX. Proportional logarithms, viz. log 10800″ − log x from $x = 0$ to $x = 10800''$ ($= 3°$ or 3^h), the arguments expressed in degrees or hours, minutes, and seconds at intervals of 1″, to 4 places.

The book contains 34 tables, the rest of which are nautical. The navigation &c. occupies 299 pages.

Rios, 1809. The first edition was published in 1806; and this is the second. The tables are identical with those in the Spanish reprint of 1850 described below, so that the description of the latter will suffice. The numbers both of the tables and the pages are the same in both; and the only difference is that the headings of the tables &c. in the 1809 edition are in English. A list of errors in this edition is given in the reprint of 1850.

Although the title of the Spanish reprint is given in the list in § 5, we have

thought it would be more convenient to give the work the date of 1809, as this more properly represents the time of appearance than does 1850.

T. XIV. Proportional logarithms for every second to 3°, to 5 places. This table only differs from T. 74 of RAPER in there being 5 instead of 4 places given.

T. XV. Five-figure logarithms of numbers from 10 to 10,200, with the corresponding degrees, minutes, and seconds.

T. XVI. (pp. 382–472). Log sines, cosines, secants, cosecants, versed, coversed, suversed, and sucoversed from 0° to 45° at intervals of 15″ (with arguments also in time), to 5 places. The term "versed" (*versos*) is used for semiversed sine for brevity, and so for the others; the table thus gives $\log \frac{1}{2}(1 \pm \cos x)$ and $\log \frac{1}{2}(1 \pm \sin x)$. The log sines, cosines, &c. are on the left-hand pages, and the log versed &c. on the right-hand pages. The table, altered in arrangement so as to make it quadrantal, is reproduced in STANSBURY, 1822. There are also given some small tables to convert arc into time, and *vice versâ*, on p. 472.

These tables are all included under the heading 'Tablas logaritmicas y tablas para convertir partes de circulo en tiempo y viceversa.'

A list of errata in the London edition of 1809 is given at the beginning of the edition of 1850.

Roe. T. I. Seven-figure logarithms of numbers from 1 to 100,000, with characteristics unseparated from the mantissæ. All the figures of the number are given at the heads of the columns, except the last two, which run down the extreme columns; 1 ... 50 on the left hand, and 50 ... 100 on the right-hand side. The first four figures (counting the characteristics) are printed at the top of the columns. There is thus an advance halfway towards the modern arrangement, and the final step was made by JOHN NEWTON (1658). This is the first complete seven-figure table that was published. It is formed from VLACQ by leaving out the last three figures, *without* increasing the seventh when they are greater than 500.

T. II. Logarithmic sines and tangents for every hundredth part of a degree (viz. $\frac{1}{9000}$ part) of the quadrant, semiquadrantally arranged, to 10 places, with characteristics, which, however, are separated by a comma.

The work is very rare: the copy we have seen belongs to the Royal Society.

Rümker, 1844. T. I. Six-figure logarithms of numbers from 1000 to 10,000, arranged consecutively in columns and divided into decades, with the proportional parts for each decade by the side of it.

T. II. Log sines and tangents for every ten seconds to 2°, and log sines, tangents, and secants for every minute from 0° to 45°, with differences, to 6 places; the logarithms written at length.

T. III. Natural versed sines to every minute to 180°, with proportional parts for the seconds, to 6 places.

T. IV. *Logarithmen-Steigezeit*, viz. log versed sines for every minute to 12^h, to 6 places, with differences for one second (corresponding to $0^h\ 0^m$: the table gives 0 instead of $-\infty$).

T. XXIV. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of RAPER.

In all cases the logarithms are written at length. The other tables are nautical.

***Salomon,** 1827. This work we have not seen; but as Rogg has given a description of several of the tables, and we see no likelihood of meeting with the book, we here give his account. There are 13 tables, of which the most noteworthy are the following:—

T. I. Squares, cubes, square and cube roots (to how many places is not stated) of all numbers from 1 to 10,000 conveniently arranged.

T. II. Factors (except 2, 3, 5, and 11) of numbers from 1 to 102,011.

T. VII. Six-figure logarithms of numbers to 10,800 (the last 800 to 7 places).

T. VIII. Briggian and hyperbolic logarithms of all numbers from 1 to 1000, and of primes from 1009 to 10,333, to 10 places.

T. IX. Logarithmic canon for every second of the first two degrees, and then for every ten seconds of the rest of the quadrant (to 6 or 7 places, we suppose).

T. XII. Natural sines and tangents for every minute, with differences. Rogg adds that the printing and paper are good for Germany, but that he has made no comparison to determine the correctness of the table; the two pages of errata, however, show (he remarks) that there was not so much care taken as with SHERWIN, GARDINER, CALLET, HUTTON, TAYLOR, or VEGA. Rogg's account is to be found on pp. 254 and 399 of his 'Bibliotheca.' See also Gernerth's tract.

***Schlömilch** [1865?]. Five-figure logarithms to 10,909; table for the conversion of Briggian into hyperbolic logarithms; logarithms of constants; circular measure of degrees, minutes, and seconds; natural functions for every ten minutes of the quadrant; log functions for every minute; reciprocals, square and cube roots, and hyperbolic logarithms of numbers to 100; elliptic quadrants; physical and chemical constants.

The above description is taken from an advertisement.

Schmidt, 1821. [T. I.] Five-figure logarithms to 100, and from 1000 to 10,000, with proportional parts.

[T. II.] Log sines and tangents for every minute of the quadrant (semi-quadrantally arranged), to 5 places, with differences.

[T. III.] Natural sines (to 5 places) and tangents (to 5 places when less than unity, above that to 6 figures) for every minute of the quadrant.

[T. IV.] Circular arcs, viz. circular measure of 1°, 2° ... 90°, 120° ... 300°, 360°, of 1′, 2′ ... 60′, and of 1″, 2″ ... 60″, to 12 places.

[T. V.] Squares and cubes of all numbers from unity to 1000, with two subsidiary tables to extend the table to 10,000; the latter are of double entry, and contain:—(i) $(2\,a + c)\,c$ for $c = 1, 2 \ldots 9$ and $a = 10, 11 \ldots 99$, and $b\,c$ and $2\,b\,c$ for the same values of c and for $b = 1, 2 \ldots 9$; and (ii) $(3\,a^2 + 3\,a\,c + c^2)\,c$ for $c = 1, 2 \ldots 9$, and $a = 10, 11 \ldots 99$.

There are a few other small tables for the solution of triangles, refractions, &c.

Schrön, 1860. T. I. Seven-figure logarithms to 1000, and from 10,000 to 108,000 (the last 8000 being to 8 places), with proportional parts to one place of decimals, so that they are in fact multiples. The change in the line is denoted by an asterisk prefixed to the fourth figure of all the logarithms affected. The degrees, minutes, &c. corresponding to every number (regarded as that number of seconds) in the left-hand column, and also corresponding to these numbers divided by 10, are given. At the bottom of the page also S and T (and also the log sine and tangent) are added for every 10″ (§ 3, art. 13, p. 54). When the last figure has been increased there is a bar subscript, which, being more obtrusive, is not so good as BABBAGE's point. The table is followed by the first 100 multiples of the modulus and its reciprocal, to 10 places.

T. II. Log sines and tangents for every ten seconds of the quadrant, to 7 places, with very complete proportional-part tables (or more properly multiples of the differences). The increase of the last figure is noted as in T. I.

T. III. Interpolation table, viz. the first 100 multiples of all numbers

from 40 to 410. The table occupies 75 pages; and on each double page are given the proportional parts to hundredths of 1, 2, 3, 4, and 5 (viz. the first 100 multiples divided by 100 and contracted to one decimal place). The last page of the book is devoted to a table for the calculation of logarithms, and contains common and hyperbolic logarithms of n, $1{\cdot}0n$, $1{\cdot}00n$, &c., n being any single digit (or in other words, of $1+\frac{x}{10^n}$ from $x=1$ to $x=9$ and $n=1$ to $n=10$), to 16 places. The figures are beautifully clear, and the paper very good. The tables are of their kind very complete indeed.

We have seen errata in this work advertised in different numbers of Grunert's 'Archiv der Mathematik und Physik.' See SCHRÖN, 1865, below.

Schrön (London edition), 1865. De Morgan remarked that in England, though there existed minute- and second-tables of trigonometrical functions, there was no good ten-second table; and on learning from the publishers that an English edition of SCHRÖN was contemplated, he offered to write a short preface, as, accuracy being taken for granted, these appeared to him to be the most powerful and best ten-second tables he had seen: his offer, however, was accompanied by the condition that a careful examination should be made by Mr. Farley, sufficient to judge of the accuracy of the work, and that the result should be satisfactory. Mr. Farley accordingly examined 24 pages selected at hazard, wholly by differences and partly by comparison with CALLET; and the pages were found to be totally free from error; so that the general accuracy of the tables was assured. They are printed from the same plates as in the German edition described above; and the tabular matter in the two seems identical in all respects.

Schulze, 1778. [T. I.] Seven-figure logarithms to 1000, and from 10,000 to 101,000, with differences and proportional parts. The proportional parts at the beginning of the table, which are very numerous, are printed on a folding sheet.

A page at the end of this table contains the first nine multiples of the modulus and its reciprocal, to 48 places; also e to 27 places, and its square, cube....to its 25th power, also its 30th and 60th powers, the number of decimals decreasing as the integral portion increases. Log π (hyperbolic and Briggian) is also given.

[T. II.] Wolfram's hyperbolic logarithms of numbers *to* 48 *places*. The numbers run from unity to 2200 at intervals of unity, and thence to 10,009, only not for all numbers; "von 2200 bis 10,000 ist sie hingegen nur für die Prim- und etwas stark componirte Zahlen berechnet, weil das Uebrige durch leichtes Addiren kann gefunden werden" (Preface). De Morgan says "for all numbers not divisible by a single digit;" but this is incorrect, as 2219, 2225, &c. are divisible by single digits, while 9809 (least factor 17), 9847 (least factor 47) do not occur. In fact, at first a great many composite numbers are tabulated, and near the end very few, if any. All the primes, however, seem to be given; and by the aid of Wolfram's tables we may regard all hyperbolic logarithms of numbers below 10,000 as known. Space is left for six logarithms, which Wolfram had been prevented from computing by a serious illness. These were supplied in the 'Berliner Jahrbuch,' 1783, p. 191. Mr. GRAY points out an error in Wolfram's table; viz. in log 1409, ...1666....should be....1696....('Tables for the formation &c.,' 1865, p. 38).

On Wolfram, see § 3, art. 16.

[T. III.] Log sines and tangents for every second from 0° to 2°, to seven places: the sines are on the left-hand pages, the tangents on the right-hand; no differences.

[T. IV.] Logistic logarithms to every second to one degree, to four places. The pages in [T. III.] and [T. IV.] are not numbered.

[T. V.] is the first table in the second volume. It contains:—natural sines, tangents, and secants to seven places, with differences; log sines and tangents to seven places, with differences (from 0° to 4° the simple difference, and from 4° to 45° one sixth part of the difference, is given); and *Napierian* (see § 3, art. 17) log sines and tangents to eight places, without differences; all for every ten seconds for the first four degrees, and thence for every minute to 45°. The Napierian logarithms (see first page of Preface to the second volume) are taken from the 'Canon Mirificus' of Napier, augmented by Ursinus. The arrangement of the table is not very convenient, but perhaps the best possible.

[T. VI.] (pp. 262, 263). First nine multiples of the sines of 1°, 2°, 3° .... 90°. One or two constants are given on p. 264.

[T. VII.] Circular measure of all angles from 1° to 360° at intervals of 1°. This is followed by similar tables for minutes from 1′ to 60′ at intervals of 1′, and for seconds from 1″ to 60″ at intervals of 1″, all to 27 places.

[T. VIII.] Powers, as far as the eleventh, of decimal fractions from ·0 to 1·00 at intervals of ·01, to eight places.

[T. IX.] Squares of numbers to 1000.

[T. X.] Cubes of numbers to 1000.

[T. XI.] Square roots of numbers to 1000, to seven places.

[T. XII.] Cube roots of numbers to 1000, to seven places.

[T. XIII.] The first six binomial-theorem coefficients, viz. $x, \frac{x(x-1)}{1 \cdot 2}, \ldots \frac{x(x-1) \ldots (x-5)}{1 \cdot 2 \ldots 6}$, for $x = \cdot 01$ to $x = 1 \cdot 00$, at intervals of ·01, to seven places.

The other tables connect the height and velocity of falling bodies, and contain specific gravities &c. A table on the last page is for the conversion of minutes and seconds of arc into decimals of an hour.

A table headed *Rationale Trigonometrie* occupies pp. 308–311, and is very interesting. It gives right-angled triangles whose sides are rational and such that tan $\frac{1}{2}\omega$ (ω being one of the acute angles of the triangle) is greater than $\frac{1}{25}$. Such triangles (though not so called here) are often known as Pythagorean. Those with sides 3, 4, and 5; and 5, 12, and 13 are the best-known cases; and 8, 15, and 17, 9, 40, and 41, 20, 21, and 29, &c. are among the next in point of simplicity. This table contains 100 such triangles; but some occur twice. It gives in fact a table of integer values of a, b, c, satisfying $a^2+b^2=c^2$, subject to the condition mentioned above: tan $\frac{1}{2}\omega$, expressed both as a vulgar fraction and as a decimal, is given, as also are ω and $90°-\omega$. For a larger table of the same kind, see Sang, 'Edinburgh Transactions,' t. xxiii. p. 757, 1864. On the whole, this collection of tables is very useful and valuable.

[**Schumacher,** 1822?]. T. V. Five-figure logarithms of numbers for every second to 10,800″ (3°), arguments expressed in degrees, minutes, and seconds.

T. VI. Log sines for every second to 3°, to five places. There is no name at all on the table; but it is assigned (and no doubt correctly) to Schumacher in the Royal Society's Library; and De Morgan, speaking of Warnstorff's Schumacher (1845), says that the original publication was Altona, 1822; but there was an earlier edition, we believe, at Copenhagen, in 1820.

Shanks, 1853. The bulk of this work ([T. I.] pp. 2–85) consists of the values of the terms in Mr. Shanks's calculation of the value of π by Machin's

formula, $\pi = 16 \tan^{-1} \frac{1}{5} - 4 \tan^{-1} \frac{1}{239}$. The terms in the expansion both of $\tan^{-1} \frac{1}{5}$ and $\tan^{-1} \frac{1}{239}$ are given separately to 530 places. The former occupy 60 pp. and extend to $\frac{1}{747 \cdot 5^{747}}$; and the latter occupy 24 pp. and extend to $\frac{1}{219 \cdot 239^{219}}$. While the work was passing through the press Mr. Shanks extended his value of π to 607 decimals; and to this number of places it is given on pp. 86 and 87 of the book.

[T. II.] (pp. 90–95) gives every twelfth power of 2 (viz. 2^{13}, 2^{25}, &c.) as far as 2^{721} (which contains 212 figures).

On p. 89 are given the values of e, $\log_e 2$, $\log_e 3$, $\log_e 5$, and $\log_e 10$, to 137 places, and the modulus to 136. Values of these quantities were given also by Mr. Shanks to 205 places (Proc. Roy. Soc. vol. vi. p. 397). The value of e was verified by the reporter to 137 places by calculation from a continued fraction (see Brit. Assoc. Report, 1871, pp. 16–18, sectional proceedings). The same writer also showed in vol. xix. p. 521 of the 'Proceedings of the Royal Society,' that Mr. Shanks's values of log 2, 3, 5, and 10 were inaccurate after the 59th place (all owing to *one* error in a series on which they depended), and deduced the correct values to 100 places. These results were verified by Mr. Shanks, who has recalculated the values of these logarithms, as well as that of the modulus, to 205 places: they are published in vol. xx. p. 27 of the 'Proceedings of the Royal Society' (1871).

Mr. Shanks's 607-place value is given in Knight's 'English Cyclopædia,' (Art. "Quadrature of the Circle") copied from the work under notice; and it has been verified by a subsequent calculation of Richter to 500 places. A list of the calculators of π, the number of places, &c. to which they have extended their calculations, with references to the places where they are to be found, is given by Bierens de Haan on a page at the beginning of his "Tables d'Intégrales Définies" in t. iv. of the Amsterdam Transactions. This page, however, does not appear in the separate copies of the tables (the 'Nouvelles Tables,' Leyden, 1867). For an extended and corrected copy of this list, see 'Messenger of Mathematics,' December 1872, and some additional corrections in the same Journal for July 1873 (t. iii. pp. 45, 46).

Some years ago Mr. Shanks calculated the reciprocal of the prime number 17389 so as to exhibit the complete circulating period, consisting of 17388 figures, and placed a copy of it in the Archives of the Royal Society. Quite recently he has extended his calculation of π to 707 decimal places (Proc. Roy. Soc. vol. xxi. p. 318). Mr. Shanks has sent us three corrections to this paper: viz. the 459th, 460th, and 461st decimals in π should be 962 instead of 834, and the 513th, 514th, and 515th decimals should be 065 instead of 193; also the 75th decimal of $\tan^{-1} \frac{1}{5}$ should be 8 instead of 7. The two corrections in π apply also to the work under notice.

Sharp, 1717. [T. I.] (p. 40). The first hundred multiples of $\frac{1}{4}\pi$, to 21 places.

[T. II.] *Areas of segments of circles.* The area of the whole circle is taken as unity; and the argument is the versed sine (or height of the segment), the diameter being taken as unity. The table then gives areas to 17 places for arguments ·0001 to ·5000 at intervals of ·0001, with differences. Thus, strictly, the argument is the ratio of the height of the segment to the diameter, and the tabular result the ratio of the area of the segment to that of the whole circle. The table occupies 50 pp., and is the largest of the kind we have seen.

[T. III.] *Table for computing the solidity of the upright hyperbolic section of a cone,* viz. for facilitating the calculation of the volumes of segments of

right circular cones, the segment being contained by the base of the cone (a segment of a circle), a hyperbolic section perpendicular to the base, and the curved surface. The use of the table (which contains 500 values of the argument and occupies 5 pp.) is explained on pp. 24–26 of the work.

[T. IV.] Briggian logarithms of numbers from 1 to 100, and of primes from 100 to 1100, to 61 places; also of numbers from 999,990 to 1,000,010, to 63 places, these last having first, second.... tenth differences added. The logarithms in this table were copied into the later editions of SHERWIN and other works.

The portion of the work which contains the tables is followed by a "Concise treatise of Polyedra, or solid bodies of many bases" (pp. 32).

The work is universally attributed to Abraham Sharp, and no doubt exists as to his having been the author.

[**Sheepshanks,** 1844.] [T. I.] Four-figure logarithms from 100 to 1000, arranged as in seven-figure tables, with proportional parts.

[T. II.] Log sines and cosines (the arguments being expressed in time) to 24^h at intervals of 1^m, to four places, with proportional parts for multiples of 10^s (to 60^s). Also log sines to 1^h for every 10^s, with differences for 1^s.

[T. III.] Log sines, cosines, tangents, and secants from 0° to 6° at intervals of 1′, thence to 84° at intervals of 10′, and then at intervals of 1′ to 90°, to four places. In the parts of the table where the intervals are 10′, differences for 1′ are given.

[T. IV.] Natural secants and tangents from 0° to 80° at intervals of 10′, with differences for 1′, and then to 86° at intervals of 1′, with differences for 10″, to four places.

[T. V.] Modified Gaussian logarithms. There are two tables. The first gives $\log\left(1+\frac{1}{x}\right)$ as tabular result for argument $\log x$, the range of $\log x$ being from ·000 to ·909 at intervals of ·001, from ·90 to 2·00 at intervals of ·01, and thence to 4·0 at intervals of ·1. The second table gives $\log\left(1-\frac{1}{x}\right)$ as tabular result, corresponding to the argument $\log x$, the range being from ·000 to 1·000 at intervals of ·001, from 1·00 to 3·00 at intervals of ·01, and from 3·0 to 6·0 at intervals of ·1: both tables to four places, with proportional parts.

[T. VI.] Log $\sin^2$ ($\frac{1}{2}$ hour angle) from 0^h to 9^h at intervals of 1^m, to four places, with proportional parts for multiples of 10^s (from RAPER).

[T. VII.] Antilogarithms, for logarithms from ·000 to 1·000 at intervals of ·001, to four places, with proportional parts.

There are also two or three astronomical tables.

De Morgan states that the work was issued under the title given in § 5 in 1846, and two years previously without name or titlepage. It is from one of these earlier copies that the above description has been written; we have seen no copy bearing either author's name or date.

Sherwin, 1741. [T. I.] (which follows p. 35 of the introduction) gives Briggian logarithms to 61 places of all numbers to 99, and the logarithms of primes from 100 to 1097, calculated by Abraham Sharp (see SHARP, 1717, [T. IV.]).

[T. II.] Briggian logarithms of thirty-five other numbers (viz. 999,981 —1,000,015), to 61 places, with first, second, third, and fourth differences, to 30 places (SHARP [T. IV.]).

[T. III.] Seven-figure logarithms of numbers to 1000, and from 10,000

to 101,000, with proportional parts. The proportional parts near the beginning of the table, being too voluminous for insertion on the page, are printed on a fly-sheet, and bound up facing the introductory page of the table.

[T. IV.] Natural and log sines, tangents, and secants for every minute, to seven places. Differences for the logarithmic functions are added, but not for the natural ones.

[T. V.] Natural and log versed sines from 0° to 90° at intervals of a minute, to seven places. Part of a page at the end of [T. V.] is occupied by a small table to convert sexagesimals into decimals, &c., and *vice versâ*.

The remaining table (of difference of latitude and departure) is not included in this Report (see § 2, art. 12).

Sherwin went through five editions; but as none were stereotyped, some of the later are less accurate than the earlier. De Morgan remarks, "Second edition, 1717; third revised by Gardiner, and the best, 1742; fifth and last, 1771, very erroneous—the most inaccurate table Hutton ever met with." In speaking of the third edition we at first thought that De Morgan should probably have written 1741 instead of 1742, as the edition we have described bears the former date, but we have since seen a copy of 1742.

We possess an edition (1726) which contains a list of "Errata for the second edition of Sherwin's Mathematical Tables" by Gardiner. In this edition, in place of [T. I.] and [T. II.] there are given two pages (pp. 28 and 29) headed "M. Brigg's (*sic*) Logarithms for all Numbers, from 1 to 100, and for all *Prime Numbers* from 100 to 200, calculated by that Ingenious Gentleman and Indefatigable Mathematician, Mr. Abr. Sharp, at Little Horton, near Bradford in Yorkshire." The logarithms are given to from 50 to 60 places (not all to the same extent).

We have also before us an edition of 1706; and the dedication, which is the same in all the editions we have seen, is dated July 12, 1705. The table on pp. 27 and 28 is the same as in the edition of 1726; but at the end of the introduction is a table of errata, which are corrected in this latter edition. The titlepage of the editions of 1705, 1706, and 1726, and perhaps other dates, runs, "Mathematical Tables.... with their Construction and Use by Mr. Briggs, Mr. Wallis, Mr. Halley, Savilian Professors of Geometry in the University of Oxford, Mr. Abr. Sharp" (the names of the authors being placed one under the other); and in the edition of 1706 is added, "The whole being more correct and complete than any Tables extant." Sherwin's name does not, therefore, occur on the titlepage at all; but the preface is signed and the tables were prepared by him, so that the work is universally known as "Sherwin's Tables." In library catalogues, however, it will generally be found entered under the name of Briggs, Wallis, Halley, or Sharp.

In the edition of 1741, the names of Briggs, Wallis, Halley, and Sharp do not appear on the titlepage, but we have "The third edition, carefully revised and corrected by William Gardiner" instead.

It will be seen that there is some confusion in the editions, as, if De Morgan is correct in saying that the second edition was published in 1717, the edition of 1726 would be the third, and that of 1741 the fourth.

The Royal Society's Library contains a copy with "1705" on the titlepage, while the edition of 1706 (which is in the library of Trinity College, Cambridge) has the date printed in Roman characters, MDCCVI.

We have seen (in the Graves Library) the fourth edition, 1761; and the British Museum contains, besides the editions of 1717 and 1742, the fifth edition, "revised and improved by S. Clark" (1772), while the Cambridge University Library has the same edition with the date 1771.

The editions we have seen are 1705 and 1706, 1717, 1726; the third edition 1741 and 1742, the fourth 1761, and the fifth 1771 and 1772. It thus appears that it was not at all an uncommon thing (probably as the impression was being made up from time to time) to advance the date by one year. The first four dates we may distribute among the first two editions as we please; most likely 1705, 1706, and 1717 for the first, and 1726 for the second.

Rogg (p. 401) gives the editions as 1706, 1742, 1763, and 1771; but elsewhere (p. 262) he speaks of the fifth as of 1785, which must be incorrect.

De Haan ('Iets over Logarithmentafels,' p. 57) gives the dates of the editions as 1706, 1717, 1726, second 1742, 1751, 1763, fifth 1771. The subject of the dates of the editions of Sherwin is discussed at some length in the 'Monthly Notices of the Royal Astronomical Society' for March and May 1873 (vol. xxxiii. pp. 344, 454, 455, 457). Mr. Lewis, in his letter to the reporter, printed in the second of these papers, mentions 1717, 1742, 1761, and 1771 as the dates of the editions he had seen, agreeing perfectly with those mentioned by De Morgan, Lalande ('Bibliog. Astron.'), and the results of our own observation. He remarks that Barlow gives 1704 and Callet 1724 as dates of editions, of which the former may be dismissed at once as an obvious blunder. The editions therefore that we have not seen, but which *may* exist, are those of 1724, 1751, and 1763. About any of these or any others we should be glad to receive information.

Rogg mentions that SHERWIN has often been confounded with GARDINER, even by Kästner and Bugge.

With regard to the accuracy of the tables, HUTTON writes (we quote from p. 40 of the Introduction to his tables, 3rd edit. 1801):—"The first edition was in 1706; but the third edition, in 1742, which was revised by Gardiner, is esteemed the most correct of any, though containing many thousands of errors in the final figures: as to the last or fifth edition, in 1771, it is so erroneously printed that no dependence can be placed in it, being the most inaccurate book of tables I ever knew; I have a list of several thousand errors which I have corrected in it, as well as in Gardiner's octavo edition."

De Haan ('Iets' &c., p. 26), speaking of the 1742 edition, says that it contains the logarithms of the numbers from 999,980 to 1,000,020 to 61 places; but on examination we find that the above description of [T. II.] is correct. The advertisement to the book itself is no doubt the source of the error; for it is there said to contain the logarithms of the 41 numbers from 999,980 to 1,000,020, whereas it really contains the logarithms of the 35 numbers from 999,981 to 1,000,015.

Sherwin's tables are of historical interest as forming part of the main line of descent from BRIGGS; and the different editions cover the greater part of the last century. The chief succession (considering only logarithms of numbers) is BRIGGS, VLACQ, ROE, JOHN NEWTON, SHERWIN, GARDINER; and then there are two branches, viz. HUTTON founded on SHERWIN, and CALLET on GARDINER, the editions of VEGA forming an offshoot.

Shortrede (Compendious logarithmic tables), 1844. Small tables of common logarithms with sexagesimal arguments, logarithms to 12,600, antilogarithms from 0 to ·999, log sines and tangents to 5′, also from 0° to 3°, and from 3° to 5° for every two minutes; all to five or six places. The tract only contains 10 pp.

Shortrede (Tables), 1844. T. I. Seven-figure logarithms to 10,800 with characteristics, but without differences, and from 10,800 to 120,000, with differences, and their first nine multiples at the bottom of the page: the num-

ber of degrees, minutes, and seconds corresponding to the numbers in the number-column multiplied by 10 is given throughout; and at the top of every page are printed, to seven places, the logarithms of certain constants, viz. of 360°, 180°, 90°, 1°, 24^h, 12^h, 3^h, 1^h, and radius (all expressed in seconds) of arc 1″, π and M the modulus. The change of figure in the line is denoted by a "nokta," the same as that employed subsequently by Mr. Sang (see SANG, § 3, art. 13); and its use is open to the same objections here as there.

T. II. Antilogarithms, viz. numbers to logarithms from ·00000 to 1·00000 at intervals of ·00001, to 7 places, with differences and multiples at the bottom of the page. The same logarithms of constants are given on the top of the page as in T. I.; and the change in the line is denoted in the same way. At the end of this table (p. 195), under the head "Useful Numbers," the logarithms of some constants are given.

T. III. (pp. 598). Log sines and tangents *to every second of the circumference,* to 7 places (semiquadrantally arranged), the arguments throughout being also given in time. The use of the word *circumference* instead of *quadrant* in this description is justified by the fact that the signs are given for the different quadrants at the top and bottom of the page: thus we have on the first page, at the top, 0° Sin +, 90° Cos—, 180° Sin —, 270° Cos +, and at the bottom 89° Cos +, 179° Sin +, 269° Cos —, 359° Cos —, and the same for the tangent and cotangent, the arguments being also expressed in time. Complete proportional parts are given throughout for tenths of a second of space, and for the first six hundredths of a second of time, both for the sine and tangent; but near the beginning of the tables coefficients of correction for first and (sometimes) second differences are added instead. The arguments, as before stated, are given also in time; so that corresponding to 1″, 2″, 3″, &c. we have $·06^s$, $·13^s$, $·20^s$, &c. This table is the most complete of the kind we know of, and is unique; the figures are clear; and the objection to the "nokta" does not apply here; in one column (p. 142) there are *two* changes on the page.

T. V. Seven-place log sines, tangents, and secants to every point and quarter point of the compass.

T. XXXVIII. Lengths of circular arcs, viz. circular measure of 1°, 2°, 3° ....180°, of 1′, 2′, ...60′, of 1″, 2″, ...60″, and of 1‴, 2‴, ...60‴, to 7 places.

T. XXXIX. Proportional parts to hundredths of the reciprocal of the modulus, viz. 2·302 ..., to 8 places.

There are thirty-nine tables in the book (T. XLI. is the last; but XXXV. and XXXVI. are accidentally omitted), the others being astronomical or meteorological &c.

The paging recommences with T. III. and proceeds to p. 634. See SHORTREDE, 1849 (next below).

Shortrede, 1849. This is a second edition of the work of 1844, and is in 2 vols. There is a preface of xxv pages to vol. i. T. I. and II. are the same as T. I. and II. in the 1844 edition; T. III. is a small ten-place table of the lengths of circular arcs. T. IV. and V. are for finding logarithms and antilogarithms to many places; viz. colog $(1 \pm ·01n)$ ...colog $(1 \pm ·01^5\, n)$, &c. are given for $n = 1, 2, \ldots 100$, to 16 places, and colog $(1 \pm ·01\, n)$...colog $(1 \pm ·01^{12} n)$ for $n = 1, 2, \ldots 10$, to 25 places (initial ciphers being omitted). There are added small auxiliary tables for facilitating the resolution of numbers into convenient factors. T. VI. The first hundred multiples of the modulus and its reciprocal to 32

places. T. VII. (which occupies six closely printed pages). Modified Gaussian logarithms. B $(=\log \overline{1+x})$ and C $\left(=\log \dfrac{x}{x+1}\right)$ are tabulated for argument A $(=\log x)$, to 5 places, from A$=5$ to 3 at intervals of $\cdot 1$; from A$=\bar{3}$ to $\bar{2}\cdot 7$ at intervals of $\cdot 01$; from A$=\bar{2}\cdot 7$ to $1\cdot 3$ at intervals of $\cdot 001$; and from A$=1\cdot 3$ to $3\cdot 0$ at intervals of $\cdot 01$, and thence to A$=5$ at intervals of $\cdot 1$. T. VIII. Log $(1.2.3..x)$ from $x=1$ to $x=1000$, to 5 and (for the arguments ending in 0) to 8 places.

Then follow 2 or 3 pp. of barometric &c. tables, and a page of constants (including a small table of $\log \dfrac{\sin \text{arc}}{\text{arc}''}$, and the same for the tangent).

The second volume contains T. III. of the 1844 edition, followed by some spherical-trigonometry formulæ, and the same page of constants as in vol. i.

In the advertisement to the second (1849) edition, Shortrede says "a small edition of this work was published in 1844, before I had an opportunity of seeing it complete, which in several respects was such as I did not like. In the present edition many alterations have been made to conform it more to my views; and for the convenience of purchasers it is now published in two separate volumes." The prices of the two volumes are, Vol. I. 12*s.*, and Vol. II. 30*s.*; it is worth noting this, as we have seen it stated that the price of Shortrede's logarithms (by which some might understand the whole work) is 12*s.* De Morgan says, "They [Shortrede's tables] first appeared in 1844; but some defects and errors having been found, the edition of 1844 was cancelled, and a new edition from corrected plates issued in 1849." This may be true; but although we have seen four copies of the 1844 edition in different libraries, we were not able to obtain a sight of the 1849 edition anywhere till we bought it. Our copy of Vol. i. is dated 1849, and of Vol. ii. 1858. There are few tables in which, *relatively to the number of figures*, the pages are so clear, and the logarithmic canon to seconds is much the most complete we have seen. Every one must agree with De Morgan that the work shows extraordinary energy and public spirit. This is the most complete second canon in existence, and is the most accessible. Only two others have been published:—Michael Taylor, 1792, which has several defects attending its use; and Bagay, 1829, which is scarce.

A list of twenty-six errors (nearly all in the antilogarithms) is given by Shortrede himself in the 'Monthly Notices of the Royal Astronomical Society' for January 1864; and a supplemental list is added in the same publication for May 1867, where he says that "the unauthorized issue in 1844 contains several others." One erratum is also given in the 'Monthly Notice' for April 1867. Shortrede adds that the great majority of the errata were communicated to him by Mr. Peter Gray.

In the 'Insurance Record' Mr. Filipowski charged Shortrede with having corrected his table by the aid of his (Filipowski's). That the charge was utterly unfounded is proved by the letter of Mr. Peter Gray ('Insurance Record,' June 9, 1871), who states that the errata in Dodson were given to Shortrede by himself (Mr. Gray); and we have seen reason to impute unfairness to Mr. Filipowski in another matter with regard to Dodson (see Filipowski, 1849, § 4). Mr. Gray has kindly placed at our disposal his copious list of errors in Dodson, of which we hope to make use in a subsequent Report.

Shortrede did not pay sufficient attention to the examination of the errata-lists of previous works; and, in consequence, his tables contain a much greater number of the hereditary errors that had descended from Vlacq than do the

best contemporary works. These errors are insignificant in themselves, except in so far as they show the acquaintance of the author of a table with the works of his predecessors. Shortrede was absent in India during the publication of the 1844 edition (which contains seven of these errors); but that of 1849 was published under his own superintendence, and still it contains six, while BABBAGE, HÜLSSE's VEGA, and other works of earlier date have but one. See 'Monthly Notices of the Roy. Ast. Soc.,' March 1873, t. xxxiii. p. 335; and Gernerth's tract (§ 3, art. 13, p. 55).

Stansbury, 1822. [T. I.] Small table to convert arc into time.

[T. II.] Proportional logarithms for every second to 3°, to 4 places. Same as T. 74 of RAPER.

T. D. Log semitangents, viz. log $\frac{\tan x}{2}$ from $x=0$ to $x=180°$ at intervals of 15′, to 3 places. This table occupies one page.

T. G. Proportional logarithms for every minute to 24^h, viz. log 1440 —log x, the arguments being expressed in hours and minutes (and also in arc), to 4 places.

T. H. (pp. 215–304). Log sines and secants, also log versed and sucoversed, from 0° to 90° at intervals of 15″ (arguments also expressed in time), to 5 places. By "versed" and "sucoversed" are meant "semiversed sine" and "semisucoversed sine" (the terms introduced by De Mendoza y Rios being used for brevity, see RIOS, 1809); so that the table gives log $\frac{1+\cos x}{2}$ and log $\frac{1+\sin x}{2}$. This table was copied from T. XVI. of RIOS; but there is a difference of arrangement, as the original table gave log sines, cosines, &c., the arrangement being semiquadrantal, while in the present work it is quadrantal.

T. X. Five-figure logarithms from 1000 to 10,000; no differences.

T. Y. Halves of natural sines, viz. $\frac{1}{2}\sin x$ from $x=0°$ to $x=90°$ at intervals of a minute, to 5 places, with proportional parts for seconds.

The other tables are nautical.

Stegmann, 1855. T. I. Six-figure logarithms to 119, and five-figure logarithms, with differences, from 1000 to 10,000.

T. II. Antilogarithms from ·0000 to ·9999, to 5 places. A few tables of atomic weights &c. are added. As in FILIPOWSKI's tables, the terminal 5 is replaced by the Roman V when it has been increased.

The preface to these tables is signed by Stegmann, but his name does not appear on the titlepage.

***Stegmann.** This work we have not seen. Three errata in it are given by Prof. Wackerbarth in the 'Monthly Notices of the Royal Astronomical Society' for April 1867: and this is the only place in which we have seen the table referred to. It is very possibly a five-figure hyperbolic logarithmic table, similar to the same author's table of common logarithms just described.

Janet Taylor, 1833. T. XVII. Log sines, tangents, and secants to every quarter point, to 6 places.

T. XVIII. Six-figure logarithms of numbers to 10,000.

T. XIX. Log sines and tangents for every 10″ to 2°, and log sines, tangents, and secants for every minute of the quadrant, to 6 places, with differences.

T. XX. Natural sines for every minute of the quadrant, to 6 places.

T. XXI. Log versed sines to 8^h at intervals of 5^s, to 5 places.

T. XXXVI. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of RAPER.

At the end of the preface Mrs. Taylor makes the following curious remark:—"Some errors have crept into the calculations from the multiplicity of entries &c.; these, I trust, will claim the indulgence of the public; for the system on which I have worked being mathematically correct, and founded on sound principles, any slight oversight in the figures can be of but little moment, and very easily rectified." It is to be presumed that this does not refer to the tables included in this Report, as they would not have been calculated afresh.

Mrs. Taylor was also the author of a work on navigation, the tables in which are described below.

Janet Taylor, 1843. T. 3. Log sines, tangents, and secants to every quarter point, to 6 places.

T. 4. Six-figure logarithms of numbers to 10,000.

T. 5. Log sines and tangents for every 10″ to 2°; and log sines, tangents, and secants for every minute of the quadrant, to 6 places, with differences.

T. 30. Log versed sines for every 5^s to 8^h, to 5 places.

T. 32. Natural sines for every minute of the quadrant, to 6 places.

T. 35. Proportional logarithms for every second to 3°, to 4 places; same as T. 74 of Raper.

Mrs. Taylor, as we learn from an advertisement, kept a nautical academy in the Minories.

Michael Taylor, 1792. [T. I.] Logarithms of numbers to 1260, to 7 places.

[T. II.] Logarithms of numbers from 10,000 to 101,000, to 7 places, with differences and proportional parts. The change in the third figure, in the middle of the line is not marked.

[T. III.] Table of log sines and tangents *to every second of the quadrant,* to 7 places (semiquadrantally arranged). The change in the leading figures, when it occurs in the middle of the column, is not marked at all; and it requires very great care in using the table to prevent errors from this cause. If any one is likely to have to make much use of the table, it will be worth his while to go through the whole of it, and fill in with ink the first 0 after the change (making it a black circle such as is used to denote full moon in almanacs), and also to make some mark that will catch the eye at the top of every column containing a change. This will be a work of considerable labour, but is absolutely necessary to ensure accuracy. It is no doubt chiefly on account of the absence of any mark at a change that Bagay has so completely superseded this table, though difference of size &c. are also in favour of the former.

[T. I.] and [T. II.] present no novelty; but [T. III.] is an enormous table, containing about 450 pages, with an average number of about 7750 figures to a page, so that it contains nearly three millions and a half of figures. The left-hand pages contain sines and cosines, the right-hand tangents and cotangents. This is unfortunate, as the sines and cosines (which are used far more frequently than the tangents and cotangents) are thus separated at least a foot from the computer's paper as he works with the table on his left; and it is well known that the number of errors of transcription is proportional to the distance the eye has to carry the numbers. [T. III.] was calculated by interpolation from Vlacq's 'Trigonometria Artificialis,' to 10 places, and then contracted to 7; so that the last figure should always be correct. Taylor was a computer in the Nautical Almanac Office; he unfortunately died almost at the moment of the completion of his work, only five pages remaining unfinished in the press at the time of his death. These

were examined, and the introduction &c. written, by Maskelyne. Some errata, found among Taylor's papers, are given on p. 64 of the work; and a list of nineteen errata signed by Pond is published in the 'Nautical Almanac' for 1833. To this list is appended the remark:—"The above errata were detected by collating Taylor's Logarithms with the French manuscript tables, now the property of C. Babbage, Esq. The arrangement for this examination was made by the late lamented Dr. Young; a few days only before his death he gave directions for its completion.—J. POND."

We do not know any thing further with regard to this examination, though the fact that certain errors were found in Taylor by comparison with the French tables is well known; but there must be some mistake, as the French tables could not have been even temporarily the property of Babbage. In the preface to his tables BABBAGE states that while on a visit to Paris he availed himself of the opportunity of consulting the great manuscript tables preserved at the Observatory, and that he "enjoyed every facility for making the comparisons which were requisite for this purpose [the preparation of his seven-figure table], as well as making extracts necessary to me for other calculations."

Bagay intimates in his preface that he had found 76 errors in Taylor.

Taylor was also the author of the Sexagesimal Table (§ 3, art. 9); and we cannot but admire the undaunted perseverance that could enable him to complete such monuments of industry in addition to his routine work as computer in a laborious office.

Thomson, 1852. T. I. One-page table to convert arc into time.

T. X. *Logarithms for finding the correction of the sun's declination* &c., viz. log 1440 − log x, from $x=1$ to $x=1440$, to 4 places.

T. XI. *Logarithms of the latitude and polar distance*, viz. log secants to every minute of the quadrant, to 5 places, without differences; quadrantally arranged.

T. XII. *Logarithms of the half sum and difference*, viz. log sines and cosines to every minute of the quadrant, to 5 places, without differences; quadrantally arranged.

T. XIII. *Logarithms of the apparent time or horary angle*, viz. 2 log sin $\frac{x}{2}$ from $x=0^h$ to $x=9^h$ at intervals of 10^s, with proportional parts for seconds, to 5 places.

T. XV. *Logarithms of the apparent altitudes*, viz. log cosec x — ·5400, from $x=0°$ to $x=89°$, at intervals of a minute, to 4 places.

T. XVI. *Logarithms of the apparent distance*, viz. log sines and tangents for every minute, from 18° to 90°, to 4 places.

T. XIX. Four-place proportional logarithms for every second to 3°; same as T. 74 of RAPER.

T. XXIII. *Logarithms of the sum and difference*, viz. log sin $\frac{x}{2}$, from $x=0°$ to $x=180°$, at intervals of a minute, to 6 places.

T. XXIV. Six-figure logarithms of numbers from 1000 to 10,000, with differences and tables for interpolating at the foot of the page. In this book it is only required to find numbers corresponding to logarithms; and the tables are constructed with this view. There are given, therefore, the usual differences (called *first differences*), and the approximate results of the division of 1, 2, 3,. . . . 10, and ten or more higher numbers by them. By the *second difference* is meant the difference between the given logarithm and the logarithm next below it in the table.

T. XXV. Natural versed sines for every minute to 120°, to 6 places, with proportional parts for seconds.

The other tables are nautical &c.

Trotter, 1841. [T. I.] Six-figure logarithms of numbers to 10,000, with differences. This is followed by a small table to convert Briggian into hyperbolic logarithms &c.

[T. II.] Log sines, tangents, and secants to every quarter point, to 6 places.

[T. III.] Log sines and tangents for every fifth minute of the quadrant, to 6 places.

[T. IV.] Natural sines and tangents for every fifth minute of the quadrant, to 6 places.

[T. V.] Areas of circular segments, to 6 places; same as T. XIII. of HANTSCHL.

[T. VI.] Squares, cubes, square and cube roots (to 6 places) for numbers from 1 to 1000.

[T. VII.] Circular measure of 1°, 2°, ... 180°, of 1′, ... 60′, of 1″, ... 60″, and of 1‴, ... 60‴, to 7 places.

[T. VIII.] Reciprocals of numbers from 1 to 500, to 9 places.

[T. IX.] Logarithms of numbers from 1000 to 1100, to 7 places.

[T. X.] Lengths of sides of inscribed and circumscribed polygons (up to a 20-sided figure), the diameter of the circle being unity, to 7 places.

[T. XI.] Hyperbolic logarithms of numbers from 1 to 100, to 8 places.

[T. XII.] For finding the areas of oblong and oblate spheroids. A few constants are given. The other tables are astronomical, meteorological, &c. Some trigonometry &c. is prefixed at the beginning (pp. 102).

Turkish Logarithms &c. [1834]. The book commences on the last page; and the first table gives seven-figure logarithms of numbers from unity to 10,080, arranged consecutively in columns, there being three columns of arguments and tabular results to the page. The tables begin at the last page, as before remarked, the extreme right-hand column being the first column of arguments; to the left of it is the corresponding column of tabular results, then to the left of that the second column of arguments, and so on. The table occupies 84 pp. (up to p. 85). Then "follows" a table of log sines and tangents for every minute of the quadrant (semiquadrantally arranged), the sines and cosines being side by side, and separated by some "white" from the tangents and cotangents. This table occupies 90 pp., and is followed by a similar table of natural sines and tangents (to 7 places), which also occupies 90 pp. Except that the table runs in the wrong direction, it only differs from an ordinary table in the ten digits being denoted by different marks from those to which we are accustomed. A few minutes' practice, however, is quite sufficient to get used to the new numerals; and then the table could be used as well as any other. There is no introductory or explanatory matter. The book is in the British Museum; and the place and date in § 5 are taken from the Catalogue of the Library.

Ursinus, 1827. [T. I.] Six-figure logarithms to 1000, and from 10,000 to 100,000, without differences; the values of S and T for finding log sines and tangents of angles below 2° 46′ 40″ (see § 3, art. 13) are given at the top of the page.

[T. II.] Log sines and tangents for every 10 seconds throughout the quadrant, with differences, to 6 places.

[T. III.] Longitudes of circular arcs, viz. circular measure of 1°, 2°, 3°, ... 360°, of 1′, 2′, ... 60′, and of 1″, 2″, ... 60″, to 7 places. These are followed

by a page giving the sines of 3°, 6°, 9°,....87° accurately (*i. e.* expressed as radicals).

[T. IV.] Longitudes of chords, viz. lengths of chords subtending given angles (the arguments) at the centre. The arguments proceed from 0° to 108°, at intervals of ten minutes, and thence to 180° at intervals of 1°; and the tabular results are given to 3 places.

[T. V.] *Abacus trigonometricus*, viz. natural sines, tangents, and secants, and log sines and tangents from 0° to 90° (quadrantally arranged), to every ten minutes, to 6 places. Then follow a few formulæ and constants.

Vega (Thesaurus, fol. 1794). T. I. (Magnus Canon logarithmorum vulgarium). Logarithms of numbers from 1 to 1000, without differences, and from 10,000 to 100,999, with differences, to 10 places, arranged like an ordinary seven-figure table. Proportional parts are also given, but only for the first two or three figures of the difference. The table can thus be used as an ordinary seven-figure table. A change in the fourth figure in the middle of the line is denoted by an asterisk prefixed to all the logarithms affected. T. I. occupies pp. 1–310. The last page and a half are devoted to multiples of the modulus, a few constants, and a table to convert degrees (1° to 360°) and minutes (1′ to 60′) into seconds.

T. II. (Magnus Canon logarithmorum vulgarium trigonometricus). Log sines, cosines, tangents, and cotangents, from 0° to 2° at intervals of one second, to 10 places, without differences, and for the rest of the quadrant at intervals of ten seconds, also to 10 places, with differences. All this occupies pp. 311–629, and is followed by 3 pp. containing natural sines for angles less than twelve minutes, to every second, to 12 places.

The appendix occupies pp. 633–685: p. 633 contains formulæ; and pp. 634 and 635 are occupied with tables of the longitudes of circular arcs &c. Of these the first gives the circular measure of 1°, 2°, 3°,....360°, the second of 1′, 2′, 3′,....60′, the third of 1″, 2″, 3″,....60″, all to 11 places; the fourth is a small table to express minutes and seconds as fractions of a degree. Pp. 636–640 are occupied with formulæ for the solution of triangles; and on pp. 641–684 [T. III.] we have Wolfram's great table of hyperbolic logarithms (see SCHULZE, § 4). The six omitted in SCHULZE are given; and it is stated in the preface that several errors have been corrected. The error pointed out by Mr. Gray (see SCHULZE [T. II.]) is reproduced. An error in $\log_e 1099$ is pointed out by Prof. Wackerbarth in the 'Monthly Notices of the Royal Astronomical Society' for April 1867.

Some of the errata found in VLACQ are indicated in the preface. These are, as a rule, corrected in the book; others, given in a list at the end of the introduction, were found after the printing, and must be corrected in manuscript before use. There is a third list at the end of the work (p. 685); but it is identical with that at the end of the introduction.

In some copies the list at the end of the introduction is much more complete than in others, the errors in VLACQ being marked by an asterisk, and the errata being also given in Latin and German. It is probable that additional errata were found before the edition was all made up, and that the original list was suppressed and the new one substituted. In all copies the titlepage is the same. See 'Monthly Notices of the Roy. Ast. Soc.,' June 1872, and May 1873 (p. 454).

There is a great difference in the appearance of different copies of the work. In some the tables are beautifully printed on thick white paper, with wide margin, so that the book forms one of the handsomest collections of tables we

have seen; while in others the paper is thin and discoloured; all are printed from the same type.

The arrangement of T. I. (though about half the space that would be required if the logarithms and differences were written at length is thereby saved) is not nearly so convenient as in VLACQ; 1628, for there is danger of taking out a wrong difference. Vega took great pains to free his tables of logarithms of numbers from error; and he detected *all* the hereditary errors that had descended from VLACQ which affected the first seven figures of the logarithms. But as several of these errors were corrected in his errata-list and not in the text, his successors, who failed to study these lists sufficiently, were really less accurate than he was. The last thousand logarithms that appear for the first time in this work were calculated by Lieut. Dorfmund at Vega's instigation.

T. II. is not reprinted entirely from VLACQ's 'Trigonometria Artificialis,' as the logarithms for every second of the first two degrees were calculated for the work by Lieut. Dorfmund. Vega seems not to have bestowed on the trigonometrical canon any thing approaching to the care he devoted to the logarithms of numbers, as Gauss estimates the number of last-figure errors at from 31,983 to 47,746 (most of them only amounting to a unit, but some to as much as 3 or even 4).

Vega offered a reward of a ducat for every error found in his table; and it is to be inferred from his preface that he intended to regard inaccuracies of a unit as such, so that it was fortunate that no contemporary of his made an examination similar to Gauss's. The paper of Gauss's in which this estimate occurs is entitled "Einige Bemerkungen zu Vega's Thesaurus Logarithmorum," and appeared in the 'Astronomische Nachrichten,' No. 756, for May 2, 1851 (reprinted 'Werke,' t. iii. pp. 257–264). It contains an examination of the relative numbers and magnitudes of the last-figure errors that occur in the sine, cosine, and tangent columns. It is easily shown that the tangents were formed by mere subtraction from the sine and cosine columns; but Gauss was unable to explain the fact that the cosines were more accurate than the sines, which appeared as one of the results of the examination. This question is further discussed in the 'Monthly Notices of the Roy. Ast. Soc.' for May 1873; and it is there shown by the reporter that this result is a direct consequence of the formula by means of which Vlacq calculated the table. So long as all these errors remain uncorrected, the logarithmic trigonometrical canon cannot be considered to be in a satisfactory state, as it is certainly desirable that a reliable ten-place table should exist.

We believe no perfect list of errors in Vega has been given: a number of errors in T. I. are given by Lefort ('Annales de l'Observatoire de Paris,' t. iv.); but this list could not, from the manner in which it was formed, include any errors that did not also occur in VLACQ.

A long list of errors in the trigonometrical tables of Vega is given by Gronau, 'Tafeln für die hyperbolischen Sectoren' &c. Dantzig, 1862, p. vi.

Copies of Vega are still procurable (but with difficulty and delay) from Germany, through a foreign bookseller, for about £1 10*s*. or £1 15*s*.

Vega (Manuale), 1800. T. I. Seven-figure logarithms to 1000, and from 10,000 to 101,000, with proportional parts. The change in the line is denoted by an asterisk prefixed to the fourth figure of all the logarithms affected. A few constants are given on p. 188.

T. II. Log sines, tangents, and arcs for the first minute to every tenth of a second. Although there is a triple heading, there is but a single column of tabular results, as for such small angles the sines, tangents, and arcs are equal to one another.

Log sines, cosines, tangents, and cotangents, from 0° to 6° 3′ at intervals of 10″, and thence to 45° at intervals of 1′, to 7 places, with differences for 1″ throughout.

An Appendix contains some spherical trigonometry. One page (p. 297) contains longitudes of arcs, viz. circular measure of 1°, 2°,....90°, and by intervals of 10° to 180°; also of 360°, of 1′, 2′,....60′, and of 1″, 2″,.... 60″, to 8 places. At the end some errata are given, and also some in CALLET and other works.

The description of this work, according to order of date, should follow the next; but as it is referred to in the latter it is convenient to place it first.

Vega (Tabulæ), 1797. Vol. i.—T. I. is identical, page for page, with T. I. of VEGA's 'Manuale' just described, and was most likely printed from the same type. The constants &c. on p. 188 are also identical.

T. II. is also identical with T. II. of the 'Manuale,' only with the addition of 40 more pages, containing log sines and tangents from 0° for every second to 1° 30′ 0″, to 7 places, without differences. Thus the 'Tabulæ' and the 'Manuale' agree to p. 193; then the 40 pp. are inserted in the 'Tabulæ,' and pp. 233–330 of the 'Tabulæ' are identical with pp. 193–290 of the 'Manuale,' the coincident portions of the two works being doubtless printed from the same type.

T. III. Natural sines and tangents to every minute of the quadrant, to 7 places, with differences for one second throughout.

The Appendix contains a table of circular arcs, viz. the circular measure of 1°, 2°, 3°,....360°, of 1′, 2′,....60′, and of 1″, 2″,....60″ (with the corresponding number of seconds in these angles), to 8 places, and small tables for the conversion of arc into time, and hours &c. into decimals of a day. On pp. 407–409 are given one or two constants connected with the calculation of π, the values of a few radicals, and the expression for the sine of every third degree in radicals. Some errata are given at the end of the introduction.

Vol. ii.—T. I. Table of all the simple divisors of numbers below 102,000 (2, 3, and 5 excluded); a, b, c, d are printed for 11, 13, 17, 19, to save room. This is followed by primes from 102,000 to 400,000. CHERNAC (§ 3, art. 8) found 39 errors in this table: see his preface.

T. II. Hyperbolic logarithms of numbers to 1000, and of primes from 1000 to 10,000, to 8 places. This table is followed by the first 45, 36, and 27 powers of 2, 3, and 5 respectively.

T. III. gives e^x and Briggian log e^x (the former to 7 figures, the latter to 7 places), from $x=0{\cdot}00$ to $x=10{\cdot}00$ at intervals of ·01.

T. IV. The first nine powers of numbers from 1 to 100, squares from 1 to 1000, cubes from 1 to 1000, and square and cube roots of numbers from 1 to 100, to 7 places.

T. V. Logistic logarithms, viz. log 3600—log (number of seconds in argument), for every second to 1° (=3600″), to 4 places.

[T. VI.] The first six binomial-theorem coefficients, viz. x, $\frac{x(x-1)}{1\,.\,2}\ldots\,\frac{x(x-1)\ldots(x-5)}{1\,.\,2\ldots6}$, from $x={\cdot}01$ to $x=1{\cdot}00$ at intervals of ·01, to 7 places.

This is followed by a page of tables, giving $\frac{1}{2\,.\,4}$, $\frac{1\,.\,3}{2\,.\,4\,.\,6}$, ... $\frac{1}{2\,.\,3}$, $\frac{1\,.\,3}{2\,.\,4\,.\,5}$, ... $\frac{1\,.\,3}{2\,.\,4}$ &c., to 10 places, with their logarithms to 7 places.

The rest of the book is devoted to astronomical tables and formulæ, except two remarkable tables at the end (pp. 364–371). The first of these [T. VII.] is most simply described by stating that it gives the number of shot in a pyramidal pile on a square base, the number n of shot in the side of the base being the argument; the table extends from $n=2$ to $n=40$. There is also given the number of shot in a pyramidal pile on a rectangular base, the arguments being n the number of shot in the breadth of the base, and m the number of shot in the top row (so that $m+n-1$ is the number in the length of the base). The ranges are, for n, 2 to 40, and for m, 2 to 44, the table being of double entry.

[T. VIII.] gives the number of shot in a pyramidal pile on a triangular base, the number of shot in a side of the base being the argument, which extends from 2 to 40. The other portion of the table is headed "Tabula pro acervis globorum oblongis, ab utraque extremitate ad pyramides quadrilateras appositis;" and the explanation is as follows:—Suppose we have two pyramidal piles of shot on square bases (n shot on each side) placed facing one another, at a distance equal to the sum of the diameters of m shot apart; and suppose it is required to fill this interval up, so as to make a pyramidal pile on a rectangular base, then this table gives the number for n (latus) to $n=40$, and for m (longitudo baseos) to $m=44$, the table being of double entry.

Some errata are given after the introduction.

We have seen the third edition (Leipzig, 1812); and though we have not compared it side by side with the second (here described), we feel no doubt the contents are identical; at all events the number of pages in each volume s the same, and the preface is dated 1797 in both.

Vlacq (Arithmetica Logarithmica), Gouda, 1628, and London, 1631. [T. I.] Ten-figure logarithms of numbers from 1 to 100,000, with differences. This table occupies 667 pages.

[T. II.] Log sines, tangents, and secants for every minute of the quadrant, to 10 places, with interscript differences; semiquadrantally arranged. This table occupies 90 pp.

In the English copies, by George Miller, there is an English introduction of 54 pp., and then follows a table of latitudes (8 pp.). The original edition of 1628 has 79 pp. of introduction; and a list of errata is given, which does not occur in Miller's copies (but see 'Monthly Notices of the Roy. Ast. Soc.' t. xxxiii. pp. 452, 456, May, 1873).

There were also copies with a French titlepage; and in these there is an Introduction in the same language of 84 pp. We suspect that a Dutch edition was contemplated, but that the copies of the table intended for this purpose afterwards formed Miller's English edition: no Dutch edition is known to exist (see Phil. Mag., May 1873). The titles of the three editions are given in full in § 5; in all, the tabular portion is from the same type. The bibliography of this work forms an essential part of the history of logarithms; and a good many of the references occurring in the introductory remarks to § 3, art. 13, have reference to it.

The table of logarithms of numbers contains about 300 errors, exclusive of those affecting the last figure by a unit; but a good many of these have reference to the portion below 10,000, which need never be used. This is still the most convenient ten-figure table there is (Vega, fol. 1794, is the only other); but before use the known errata should be corrected. References to all the places where the requisite errata-lists are to be found are given in the 'Monthly Notices of the Roy. Ast. Soc.' for May and June, 1872. We intend,

however, in the next Report to give a complete list of errors in the portion of the table from 10,000 to 100,000.

We succeeded in obtaining a copy of this work after some difficulty; Mr. Merrifield informs us that copies have always been procurable from abroad for about £2.

Vlacq (Trigonometria Artificialis), 1633. [T. I.] Log sines and tangents to every ten seconds of the quadrant, to 10 places, with characteristics and differences (not interscript); semiquadrantally arranged. The table occupies 270 pp.

[T. II.] Ten-figure logarithms of numbers to 20,000, with differences, printed from the same type as that used in the 'Arithmetica'(1628 and 1631) (except the last 500). A list of errata is given on the last page. The trigonometry &c. at the beginning occupies 52 pp. See § 3, art. 15 (introductory remarks), and also VEGA (fol.), 1794.

Vlacq, 1681. This is one of the numerous small editions called after Vlacq, on the Gellibrand model. The contents, shape of type, &c. are exactly the same as in HENTSCHEN (Vlacq), 1757, § 4, except that in the latter the "whites" are rather wider. The printed portion of the page of tables is $3\frac{1}{2}$ in. by $5\frac{1}{4}$ in. There are 48 pp. of trigonometry &c. in Latin. No name except Vlacq's appears in connexion with the work.

[T. I.] Natural sines, tangents, and secants, and log sines and tangents for every minute, to 7 places.

[T. II.] Logarithms of numbers from 1 to 10,000, arranged consecutively in columns, to 7 places; no differences.

In one of the copies we have seen there are several errors corrected in manuscript. This edition must be rather common in England, as we have seen several copies.

Wackerbarth, 1867. T. I. Five-figure logarithms (arranged as in seven-figure tables) to 100, and from 1000 to 10,000, with proportional parts to tenths (*i. e.* multiples of the differences). The degrees, minutes, &c. corresponding to eight numbers on the page are given at the bottom of each. At the end of this table there are added seven-figure logarithms of numbers from 10 to 100, and also from 10,000 to 11,000, the latter with proportional parts to tenths.

T. II. Log $(1.2.3\ldots.x)$ for $x=1, 2,\ldots.100$; log $(1.3.5\ldots.x)$ for $x=1, 3, 5\ldots.65$; log $(2.4.6\ldots.x)$ for $x=2, 4, 6\ldots.66$: all to 5 places.

T. III. Log sines and tangents for every second from $0'$ to $10'$; log sines and tangents for every ten seconds from $0°$ to $5°$; log sines and tangents for every minute of the quadrant: all to 5 places. Differences are added throughout, and also proportional parts to tenths (*i. e.* multiples of the differences) for every second to $5°$, and for every 10 seconds in the other portion of the table.

T. IV. Circular measure of $1°, 2°,\ldots.180°$, of $1', 2',\ldots.60'$, and of $1''$, $2'',\ldots.60''$, to 5 places. Some constants, such as the unit arc, its logarithm &c., are added.

T. V. Hyperbolic logarithms of numbers from 1 to 1010, to 5 places, with proportional parts to tenths, arranged as in seven-figure tables of Briggian logarithms; followed by the first hundred multiples of the modulus and its reciprocal, to 5 places. A few constants, π, e, &c., are given, to 30 places.

T. VI. Squares of numbers from 1 to 1000.

T. VII. Square roots (to 7 places) of numbers from 1 to 1000.

T. VIII. Natural sines, cosines, tangents, and cotangents for every $10'$ to $5°$, thence for every $20'$ to $15°$, and thence to $45°$ at intervals of $30'$, to 3 places.

T. IX. Reciprocals (to 7 places) of numbers from 1 to 1010.

T. XVII. List of primes to 1063.

T. XXI. gives some constants.

The other tables are chemical &c.

This is one of the most complete five-figure tables we have seen. The change in the leading figures, where it occurs in the middle of a line, is throughout denoted by an asterisk prefixed to the third figure of all the logarithms affected. It may be remarked that though the introduction &c. is in Swedish, the headings of the tables are in Latin.

A list of four errata in the tables is given by Prof. Wackerbarth himself in the 'Monthly Notices of the Royal Astronomical Society,' t. xxxi. No. 9 (Supplementary Number, 1871).

Wallace, 1815. [T. I.] Six-figure logarithms to 100, and from 1000 to 10,000, with differences.

[T. II.] Log sines, tangents, and secants to every minute of the quadrant, to 6 places, with differences.

[T. III.] Natural sines to every minute of the quadrant, to 5 places. This is followed by a traverse table.

The tables are preceded by 148 pp. of trigonometry &c.

Warnstorff's Schumacher, 1845. Out of 221 pages, only 21 (pp. 116–120 and 206–221) come within the scope of this Report.

[T. I.] For the conversion of arc into time, and *vice versâ*.

[T. II.] The circular measure of 1°, 2°,....90°, 95°....120°, 130°.... 360°, of 1′, 2′....60′, and of 1″, 2″,....60″, to 7 places.

[T. III.] Four-figure logarithms to 1009.

[T. IV.] Log sines, cosines, tangents, and cotangents at intervals of 4′ to 10°, and thence to 45° at intervals of 10′, to 4 places.

[T. V.] Gaussian logarithms; B and C are given for argument A from A = ·00 to 1·80 at intervals of ·01, and thence to 4·0 at intervals of ·1, to 4 places, with differences.

The other tables are astronomical.

Willich, 1853. T. XX. Seven-figure logarithms to 1200, followed by a few constants, &c.

T. XXI. Squares, cubes, square and cube roots (to 7 places), and reciprocals (to 9 places) of numbers to 343, followed by some constants.

T. A. Hyperbolic logarithms of numbers from 1 to 1200, to 7 places.

T. B. Natural and log sines, tangents, secants, and versed sines, for every half degree, to 7 places.

T. C. Circumferences and areas of circles for a given diameter, viz. πd (to 5 places) and $\frac{\pi d^2}{4}$ (to 2 places) for $d=1, 2, \ldots 9$, and from $d=1$ to 100 at intervals of ·25.

T. D. Circular measure of 1°, 2°,....180°, to 7 places.

The other tables in the work are of a very varied character.

We have also seen the second edition (1852), which does not contain the tables A to D; and we have seen a review of the seventh edition, edited by M. Marriott, 1871.

§ 5. *List of works containing Tables that are described in this Report, with references to the section and article in which the description of their contents is to be found.*

[Those works to which an asterisk is prefixed have not come under the inspection of the reporter; and the description of their contents is therefore

derived from some secondhand source. The author's name is enclosed within square brackets when it does not occur on the titlepage of the work. For other explanations see § 2, arts. 4–14, and § 6 (Postscript), arts. 2–4, 8, 10–12.]

ACADÉMIE ROYALE . . . DE PRUSSE, Publié sous la direction de l'. Recueil de Tables Astronomiques. Berlin, 1776. 3 vols. 8vo. § 4.

ADAMS, JOHN. The Mathematician's Companion, or a Table of Logarithms from 1 to 10,860 . . . London, 1796. 8vo. § 4.

AIRY, G. B., Computed under the direction of; Appendix to the Greenwich Observations, 1837. London, 1838. 4to. § 3, art. 15.

ALSTEDIUS, J. H. Scientiarum omnium encyclopædiæ tomus primus . . . Lugduni, 1649 (2 vols. fol.). § 3, art. 4.

ANDREW, JAMES. Astronomical and Nautical Tables, with Precepts . . . London, 1805. 8vo (pp. 263). § 4.

ANONYMOUS. Multiplicationstabelle, enthaltend die Producte aller ganzen Factoren von 1 bis 1000, mit 1 bis 100. Kopenhagen, 1793. 4to (pp. 247; and introduction, pp. 8). § 3, art. 1.

ANONYMOUS. Tables de Multiplication . . . Paris, 1812. § 3, art. 1.

ANONYMOUS. Tafel logistischer Logarithmen. Zugabe zu den Vega-Hülse'schen und anderen Logarithmen-Tafeln. Aus Callet's "Tables de Logarithmes." Nürnberg. Verlag von Riegel & Wiessner. 1843 (table, 7 pp.). § 3, art. 18.

ANONYMOUS (1844). See SHEEPSHANKS.

ANONYMOUS. Logarithmen. Antilogarithmen. Berlin. [On a card, 1860?] § 4.

AUXILIARY Tables. See [SCHUMACHER.]

BABBAGE, CHARLES. Table of the Logarithms of the Natural Numbers from 1 to 108000... Stereotyped. Fourth impression. London, 1841 (202 pp. and explanations &c. xx). § 3, art. 13.

[The 1838 edition (or rather *tirage*) has the following notice of errata contained in it, on the back of the titlepage: "In the logarithms of 10354, 60676 to 9, 70634 to 9, and 106611 to 9, the fourth figures ought to be small instead of large. In the list of constants the last figure of the value of ϵ should be 8 instead of 9." The tables were stereotyped from their first publication in 1827. Mr. W. Barrett Davis has called our attention to the number of last-figure unit errors in the portion of the table beyond 100,000; thus on p. 192 there are no less than fifteen such errors which are corrected in more recent works, such as SCHRÖN and KÖHLER. This portion of the table Babbage copied from CALLET.]

BABBAGE CATALOGUE. Mathematical and Scientific Library of the late Charles Babbage of No. 1 Dorset Street, Manchester Square. To be sold by Private Contract.... Printed by C. F. Hodgson and Son, Gough Square, Fleet Street [London], 1872. [The catalogue was drawn up by Mr. Robert Tucker, M.A., Honorary Secretary of the London Mathematical Society; and the library was purchased by Lord Lindsay.]

BAGAY, V. Nouvelles Tables Astronomiques et Hydrographiques . . . . Édition stéréotype... Paris, Firmin Didot, 1829. Small 4to. § 4.

BARLOW, PETER. New Mathematical Tables containing the factors, squares, cubes, square roots, cube roots, reciprocals, and hyperbolic logarithms of all numbers from 1 to 10,000, . . . London, 1814. 8vo (pp. 336, and introduction lxi). § 4.

BARLOW'S Tables of Squares, Cubes, Square roots, Cube roots, Reciprocals of all integer numbers up to 10,000. Stereotype edition, examined and corrected. (Under the Superintendence of the Society for the Diffusion of Usefu

Knowledge.) London, 1851, from the stereotyped plates of 1840. 8vo (pp. 200). § 3, arts. 4 and 7.

BATES, DAVID. Logarithmic Tables, containing the logarithms of all numbers from 1 to 10 000, together with ... Dublin, 1781. (63 pp. of tables, introduction ccxi pp., and appendix 60 pp.) § 4.

BEARDMORE, NATHANIEL. Manual of Hydrology: containing ... London, 1862. 8vo (pp. 384). § 4.

BERNOULLI, JOHN. A Sexcentenary Table ... Published by order of the Commissioners of Longitude. London, 1779. 4to (pp. 165; and introduction, viii). § 3, art. 9.

BERTHOUD, F. Les Longitudes par la mesure du temps ... Paris, 1775. Small 4to (34 pp. of tables). § 3, art. 15.

BESSEL. See [SCHUMACHER.]

BEVERLEY, THOMAS. The Mariner's Latitude and Longitude Ready-computer ... Cirencester (no date; but Appendix dated 1833). 4to (pp. 290). § 4.

BLANCHARD. See GARDINER (Avignon edition, 1770).

BONNYCASTLE, JOHN. An Introduction to Mensuration .... The fifteenth edition ... London, 1831. Small 8vo. § 3, art. 22.

BORDA, CH. Tables trigonométriques décimales ou Tables des logarithmes ... revues, augmentées et publiées, par J. B. J. DELAMBRE. Paris, An ix. [1800 or 1801]. Small 4to. § 4.

BOWDITCH, N. The improved Practical Navigator; ... to which is added a number of new Tables .... Revised, recalculated and newly arranged by THOMAS KIRBY. London, 1802. 8vo. § 4.

BREMIKER, C. Tafel der Proportionaltheile zum Gebrauche bei logarithmischen Rechnungen mit besonderer Berücksichtigung der Logarithmentafeln von Callet und Vega... Berlin, 1843. 8vo (pp. 127). § 3, art. 2.

BREMIKER, C. Logarithmorum VI decimalium nova tabula Berolinensis ... Berolini, 1852. 8vo. § 4.

BREMIKER'S VEGA. See VEGA (1857).

BREMIKER. See CRELLE (1864).

BRETSCHNEIDER, C. A. Produktentafel enthaltend die 2, 3 .... 9 fachen aller Zahlen von 1 bis 100 000. Hamburg und Gotha, 1841. 8vo (pp. 110). § 3, art. 1.

BRIGGE, H. Tables des Logarithmes ... 1626. See under DE DECKER, 1626, § 4.

[BRIGGS, HENRY.] Logarithmorum Chilias Prima. [London, 1617.] Small 8vo (pp. 16). § 3, art. 13.

BRIGGS, HENRY. Arithmetica logarithmica sive logarithmorum chiliades triginta, pro numeris naturali serie crescentibus ab unitate ad 20,000: et a 90,000 ad 100,000. Quorum ope multa perficiuntur Arithmetica problemata et Geometrica. Hos numeros primus invenit clarissimus vir Iohannes Neperus Baro Merchistonij; eos autem ex eiusdem sententia mutavit, eorumque ortum et usum illustravit Henricus Briggius, in celeberrima Academia Oxoniensi Geometriæ professor Savilianus. Deus nobis usuram vitæ dedit et ingenii, tanquam pecuniæ, nulla præstituta die. [Royal arms, I. R.] Londini, Excudebat Gulielmus Iones, 1624. folio (preface &c. 6pp., trigonometry 88 pp.; tables unpaged). § 3, art. 13.

(Some copies of this work were also published in 1631, with the same title-page as VLACQ's *Logarithmicall Arithmetike*. See § 3, art. 13.)

BRIGGS, HENRY. Trigonometria Britannica: sive de doctrina triangulorum libri duo. Quorum prior continet Constructionem Canonis Sinuum Tangentium & Secantium, unà cum Logarithmis Sinuum & Tangentium ad Gradus

& Graduum Centesimas & ad Minuta & Secunda Centesimis respondentia: A Clarissimo Doctissimo Integerrimoque Viro Domino Henrico Briggio Geometriæ in Celeberrima Academia Oxoniensi Professore Saviliano Dignissimo, paulo ante inopinatam Ipsius e terris emigrationem compositus. Posterior verò usum sive Applicationem Canonis in Resolutione Triangulorum tam Planorum quam Sphæricorum e Geometricis fundamentis petitâ, calculo facillimo, eximiisque compendiis exhibet: Ab Henrico Gellibrand Astronomiæ in Collegio Greshamensi apud Londinenses Professore constructus. [Then follow a quotation of three lines from Vieta and a diagram showing the trigonometrical functions.] Goudæ, Excudebat Petrus Rammasenius. M.DC.XXXIII. Cum Privilegio. folio. (Dedication to the Electors to the Savilian Chairs, Gellibrand's preface, and 110 pp. of trigonometry &c., followed by one page containing errata to the page signature *f*. 3 of the tables; the tables are unpaged.) § 3, art. 15.

BRIGGS. See SHERWIN.

BROWN. See WALLACE.

BROWNE, ROBERT. A new improvement of the Theory of the Moon.... London, 1731. Small 4to (pp. 14). § 3, art. 25.

BRUHNS, Dr. A new Manual of Logarithms to seven places of Decimals.... Stereotype edition. Bernhard Tauchnitz. Leipzig, 1870. 8vo (pp. 610, and introduction xxiii). § 4.

BRUNO, FAÀ DE. Traité élémentaire du Calcul des Erreurs avec des Tables stéréotypées ... Paris, 1869. 8vo (41 pp. of tables). § 3, art. 4.

BURCKHARDT, J. CH. Tables des Diviseurs pour tous les nombres du deuxième million ... Paris, 1814. 4to (pp. 112 and viii). § 3, art. 8.

BURCKHARDT, J. CH. Table des Diviseurs pour tous les nombres du troisième million ... Paris, 1816. 4to (pp. 112). § 3, art. 8.

BURCKHARDT, J. CH. Table des Diviseurs pour tous les nombres du premier million ... Paris, 1817. 4to (pp. 114, and preface &c. 4 pp.). § 3, art. 8.

*BÜRGER, J. A. P. Tafel zur Erleichterung in Rechnungen &c. 1817. See under CENTNERSCHWER, 1825, § 3, art. 3.

BYRNE, OLIVER. Practical, short, and direct Method of calculating the Logarithm of any given Number, and the Number corresponding to any given Logarithm, discovered by Oliver Byrne ... London, 1849. 8vo (pp. 82, and introduction xxiii). § 4.

BYRNE, OLIVER. Tables of Dual Logarithms, Dual Numbers, and corresponding Natural Numbers; with proportional parts of differences for single digits and eight places of decimals ... London, 1867. Large 8vo (pp. 202, and introduction pp. 40). § 3, art. 23.

BYRNE, OLIVER. Other works. See § 3, art. 23.

CALLET, FRANÇOIS. Tables portatives de Logarithmes, contenant.... Édition stéréotype, gravée, fondue et imprimée par Firmin Didot. Paris: Firmin Didot, 1795 (Tirage, 1853). 8vo (pp. 680, and introduction pp. 118). § 4.

CALLET, F. Table of the logarithms of sines and tangents .... Paris, 1795 (Tirage, 1827). Stereotyped and printed by Firmin Didot .... 8vo. § 3, art. 15.

CALLET (1843). See ANONYMOUS.

CENTNERSCHWER, J. J. Neu erfundene Multiplikations- und Quadrat-Tafeln ... mit einer Vorrede von ... J. P. Grüson und L. Ideler. Berlin, 1825. 8vo (45 pp. of tables, and introduction lv). § 3, art. 3.

CHERNAC, LADISLAUS. Cribrum Arithmeticum; sive tabula continens numeros primos ... Daventriæ, 1811. 4to (pp. 1020). § 3, art. 8.

*CLOUTH, F. M. Tables pour le Calcul des Coordonnées goniométriques. Mayen (chez l'auteur). 8vo. § 3, art. 10.

COLEMAN, GEORGE. Lunar and Nautical Tables .... Stereotype edition. London, 1846. 8vo (317 pp. of tables). § 4.

CRELLE, A. L. Erleichterungs-Tafel für jeden, der zu rechnen hat; enthaltend die 2, 3, 4, 5, 6, 7, 8, und 9 fachen aller Zahlen von 1 bis 10 Millionen ... Berlin, 1836. (pp. 1000 and explanation xvi.) § 3, art. 1.

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HERWART AB HOHENBURG. Tabulæ arithmeticæ Προσθαφαιρεσεως Universales, quarum subsidio numerus quilibet, ex multiplicatione producendus, per solam additionem: et quotiens quilibet, e divisione eliciendus, per solam subtractionem, sine tædiosâ & lubricâ Multiplicationis, atque Divisionis operatione, etiam ab eo, qui Arithmetices non admodum sit gnarus, exactè, celeriter & nullo negotio invenitur. È museo Ioannis Georgii Herwart ab Hohenburg, V. I. doctoris, ex assessore summi tribunalis Imperatorii, et ex Cancellario supremo serenissimi utriusque Bavariæ Ducis, suæ serenissimæ Celsitudinis Consiliarii ex intimis, Præsidis provintiæ Schuabæ, & inclytorum utriusque Bavariæ Statuum Cancellarii. Monachii Bavariarum, ex officina Nicolai Henrici. Anno Christi M.DC.X. obl. folio (pp. 999 and introduction 7 pp.). § 3, art. 1.

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LAMBERT, J. H. Supplementa tabularum logarithmicarum et trigonometricarum . . . . cum versione introdutionis (*sic*), Germanicæ in Latinum ser-

monem, secundum ultima auctoris consilia amplificata. Curante ANTONIO FELKEL. Olisipone, 1798. 8vo (pp. 198 and introduction lxxv). § 4.

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LAUNDY, SAMUEL LINN. Table of Quarter-squares of all integer numbers up to 100,000, by which the product of two factors may be found by the aid of Addition and Subtraction alone... London, 1856. 8vo (pp. 214 and introduction xxviii). § 3, art. 3.

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LESLIE, JOHN. The Philosophy of Arithmetic . . . . with tables for the multiplication of numbers as far as one thousand . . . Second edition, improved and enlarged. Edinburgh, 1820. 8vo (pp. 258). § 3, art. 3.

LITTROW, C. L. VON. Hülfs-Tafeln für die Wiener Universitäts-Sternwarte. Zusammengestellt im Jahre 1837 . . . 8vo (pp. 88). § 3, art. 12.

LUDOLF. Tetragonometria tabularia, quâ per tabulas quadratorum à Radice quadrata 1. usque ad 100 000 . . . Autore L. JOBO LUDOLFFO, P. P. Math. in Universitate Hierana ibidemque Senatore. Amstelodami, 1690. Small 4to (introduction, 150 pp., and tables about 420 pp.). § 3, art. 4.

LYNN, THOMAS. Horary tables, for finding the time by inspection . . . London, 1827. 4to (300 pp. of tables). § 4.

MACKAY, ANDREW. The Theory and Practice of finding the Longitude . . . with new tables. In 2 vols., the third edition, improved and enlarged . . . London, 1810. 8vo (vol. ii. contains about 340 pp. of tables). § 4.

MAGINI, J. A. Tabula tetragonica seu quadratorum numerorum cum suis radicibus ex qua cujuscunque numeri perquam magni minoris tamen triginta tribus notis, quadrata radix facile, minimaque industria colligitur. Venetiis, 1592. § 3, art. 4.

MAGINUS, J. A. . . . De Planis triangulis liber unicus. De dimetiendi ratione . . . libri quinque. Venetiis, 1592. Small 4to (contains the Tabula Tetragonica, see MAGINI above). § 3, art. 4.

MARIE. See LALANDE (1829).

MARRIOTT. See under WILLICH, § 4.

MARTIN, C. F. Les tables de Martin, ou le régulateur universel . . . . troisième édition. Paris, 1801. 8vo. § 3, art. 1.

MASERES, FRANCIS. The Doctrine of Permutations and Combinations . . . together with some other useful tracts . . . London, 1795. 8vo. § 4.

[MASKELYNE, NEVIL.] Tables requisite to be used with the Nautical Ephemeris . . . Published by order of the Commissioners of Longitude. The third edition, corrected and improved. London, 1802. 8vo (206 pp. of tables, and appendix (see next below) 106 pp. of tables). § 4.

[MASKELYNE, NEVIL.] Appendix to the third edition of the Requisite Tables . . . [London, 1802]. 8vo (pp. 106). § 4.

MASKELYNE. See MICHAEL TAYLOR (1792).

MASSALOUP, J. V. Logarithmisch-trigonometrische Hülfstafeln . . . Handbuch für Geometer, Markscheider . . . Leipzig, 1847 (pp. 667 and introduction xii). § 3, art. 10.

[MATTHIESSEN, E. A.] Tafel zur bequemern Berechnung des Logarithmen der Summe oder Differenz zweyer Grössen welche selbst nur durch ihre Logarithmen gegeben sind. Altona, 1818. Large 8vo (pp. 212 and introduction 53). There is also a Latin titlepage. § 3, art. 19.

[MAYNARD, SAMUEL.] A table containing useful numbers often required in calculations, together with their logarithms. 8vo (pp. 12, numbered 169–180). From Templeton's 'Millwright and Engineer's Pocket Companion' [see title under TEMPLETON]. It is stated on the first page that a portion of the table had appeared in other publications, and in particular in KEITH's 'Measurer,' 24th edit. 1846, by the same editor (Maynard). § 3, art. 24.

MENDOZA. See RIOS.

MERPAUT, J. M. Tables Arithmonomiques fondées sur le rapport du rectangle au carré, ou le calcul réduit à son dernier degré de simplification . . . Vannes, 1832. 16mo (500 pp. of tables, introduction 40 pp.). § 3, art. 3.

MICHAELIS. See under HULSSE's VEGA, § 4.

MINSINGER, Prof. Die gemeinen oder Briggischen Logarithmen der Zahlen . . . Augsburg, 1845. 8vo (31 pp. of tables and introduction &c. vi). § 4.

MONTFERRIER, A. S. DE. Dictionnaire des sciences mathématiques pures et appliquées . . . Tome troisième (Supplément). Paris, 1840. folio. § 3, art. 13.

MONTUCLA (Histoire des Mathématiques). § 2, art. 3.

[MOORE, SIR JONAS.] A canon of the squares and cubes of all numbers under 1000. Of the squared squares under 300. And of the square cubes and cubed cubes under 200 . . . [London, 1650 ?] § 3, art. 4.

MOORE, SIR JONAS. Excellent Table for the finding the Periferies or Circumferences of all Ellipses or Ovals . . . (no place or date. ? London, 1660). 1 page folio. § 3, art. 22.

MOORE, SIR JONAS. A new Systeme of the Mathematicks . . . In 2 vols. Vol. ii. (Tables). London, 1681. 4to (351 pp. of tables). § 4.

[MOORE, SIR JONAS.] A Table of Versed sines both natural and artificial. 4to. [London, 1681] (pp. 90). § 4.

MOORE, J. H. The new Practical Navigator; being a complete epitome of navigation, to which are added all the Tables requisite . . . The nineteenth edition, enlarged and carefully improved by JOSEPH DESSIOU. London, 1814. 8vo. § 4.

MOUTON's sines &c. to every second. See GARDINER (Avignon reprint, 1770).

MÜLLER, J. H. T. Vierstellige Logarithmen der natürlichen Zahlen und Winkel Functionem . . . (Preface dated from Gotha, 1844.) 8vo (25 pp. of tables). § 4.

*MULTIPLICATION, Tables de . . . Paris, 1812. § 3, art. 1 (Introductory remarks).

MURHARD (Bibliotheca Mathematica). § 2, art. 3.

NAPIER. Mirifici Logarithmorum Canonis descriptio, Ejusque usus, in utraque Trigonometria; ut etiam in omni Logistica Mathematica, Amplissimi, Facillimi, & expeditissimi explicatio. Authore ac Inventore, IOANNE NEPERO, Barone Merchistonii, &c. Scoto. Edinburgi, Ex officinâ Andreæ Hart Bibliopôlæ, CIↃ.DC.XIV. [On an ornamented titlepage.] 4to (dedication, preface &c. 6 pp., text 57 pp., tables 90 pp.). § 3, art. 17.

Napier. Mirifici logarithmorum canonis constructio ; Et eorum ad naturales ipsorum numeros habitudines; unà cum Appendice, de aliâ eâque præstantiore Logarithmorum specie condendâ. Quibus accessere Propositiones ad triangula sphærica faciliore calculo resolvenda: Unà cum Annotationibus aliquot doctissimi D. Henrici Briggii, in eas & memoratam appendicem. Authore & Inventore Ioanne Nepero, Barone Merchistonii, &c. Scoto. [Typographical ornament, a thistle.] Edinburgi, Excudebat Andreas Hart. Anno Domini 1619. 4to (preface 2 pp. and text 67 pp.). § 3, art. 17.

[The above is a transcript of the titlepage of the 'Constructio;' but in the only copy of this work that we have seen it is immediately preceded by an ornamental titlepage, which, as far as the ornamentation is concerned, is a *facsimile* of that of the 'Descriptio,' 1614. The letterpress, however, is very different, and runs, "Mirifici logarithmorum canonis descriptio, Ejusque usus, in utraque Trigonometria ; ut etiam in omni Logistica Mathematica, amplissimi, facillimi, & expeditissimi explicatio. Accesserunt opera posthuma: Primò, Mirifici ipsius canonis constructio, & Logarithmorum ad naturales ipsorum numeros habitudines. Secundò, Appendix de aliâ, eâque præstantiore Logarithmorum specie construendâ. Tertiò, Propositiones quædam eminentissimæ, ad Triangula sphærica mirâ facilitate resolvenda. Autore ac Inventore Ioanne Nepero, Barone Merchistonii, &c. Scoto. Edinburgi, Excudebat Andreas Hart. Anno 1619." This would imply that the 'Descriptio' and 'Constructio' were issued together in 1619 ; and whether this was so or not, it shows that such was intended. Some writers speak of a reprint of the 'Descriptio' in 1619 ; but this title may be all their authority, as few of those who have written on the subject seem to have looked beyond the titlepages of the works they were noticing. On the other hand, of course, the 'Descriptio' may have been torn out from the copy before us. The 'Constructio' is a much rarer work than the 'Descriptio ;' we have seen half a dozen copies of the latter and but one of the former (Camb. Univ. Lib.). In any case, as the leading words of the title of the 'Constructio' (on the first titlepage) are "Mirifici logarithmorum canonis descriptio," it could only be distinguished from the 'Descriptio' in most library catalogues by the date 1619. We have thought it worth while, since the description in § 3, art. 17 (p. 73), was printed, to add the first title of the work containing the 'Constructio,' and to point out the uncertainty relating to the reprint of the 'Descriptio,' in hopes that some one may settle the matter. The 1619 edition of the 'Descriptio' (supposing there to have been one of this date) is the only book of importance relating to the early spread of logarithms of which we have seen no copy; and the question of its publication is almost the only point of bibliography, in reference to the tables of this time, that we are obliged to leave undecided for the present.]

Neper, Nepair, or Nepper. See Napier.

Newton, John. Trigonometria Britanica (*sic*): or, the doctrine of triangles, In Two Books. . . . The one Composed, the other Translated, from the Latine Copie written by Henry Gellibrand, . . . A table of logarithms to 100.000, thereto annexed, With the Artificial Sines and Tangents, to the hundred part of every Degree ; and the three first Degrees to a thousand parts. By John Newton . . . London : MDCLVIII. fol. (Dedication and preface 6 pp., trigonometry 96 pp. ; tables unpaged.) § 4.

Norie, J. W. A complete set of Nautical Tables containing *all* that are requisite . . . Eighth (stereotype) edition. London, 1836. 8vo (360 pp. of tables). § 4.

Norie, J. W. A complete epitome of Practical Navigation . . . Thirteenth

(stereotype) edition, considerably augmented and improved. London, 1844. 8vo (360 pp. of tables). § 4.

[We have also seen the "fourteenth (stereotype) edition....by George Coleman," 1848, the "twelfth (stereotype) edition," 1839, the "eleventh edition," 1835, all containing 360 pp. of tables—and, besides, an edition of 1805 containing 252 pp. of tables, in which it is stated that the tables were published two years previously under the title "Nautical Tables."]

NORWOOD, RICHARD. Trigonometrie, or the Doctrine of Triangles . . . performed by that late and excellent invention of logarithms . . . London, 1631, Small 4to. § 4.

OAKES, Lieut.-Col. W. H. Table of the reciprocals of numbers from 1 to 100,000, with their differences, by which the reciprocals of numbers may be obtained up to 10,000,000... London, 1865. 8vo (205 pp. of tables and xii of introduction). § 3, art. 7.

OAKES. Machine table for determining primes and the least factors of composite numbers up to 100,000. Dedicated, by permission, to Professor De Morgan. By Lieut.-Col. W. H. OAKES. Printed and published by Charles and Edwin Layton. ... London, 1865. § 3, art. 8.

OPPOLZER, THEODOR. Vierstellige logarithmisch-trigonometrische Tafeln. . . . Wien, 1866 (pp. 16). § 4.

OPUS PALATINUM. See RHETICUS.

OTHO. See RHETICUS (Opus Palatinum).

OUGHTRED, WILLIAM. Trigonometrie, or, The manner of calculating the Sides and Angles of Triangles, by the Mathematical Canon, demonstrated . . . published by Richard Stokes and Arthur Haughton . . . . London, 1657. Small 4to. (Trigonometry 36 pp., tables 240 pp.). § 4.

OZANAM, M. Tables des sinus tangentes et secantes et des logarithmes des sinus et des tangentes . . . Paris, 1685. Small 8vo. § 4.

PARKHURST. Astronomical Tables, comprising logarithms from 3 to 100 decimal places, and other useful Tables. By HENRY M. PARKHURST. Revised edition. Printed and published by Henry M. Parkhurst (Short Hand Writer and Law Reporter), No. 121 Nassau Street, New York City. 1871. 12mo (176 pp. of tables, 66 pp. of formulæ, explanations, &c.). § 4.

PASQUICH, IOANNES. Tabulæ logarithmico-trigonometricæ contractæ cum novis accessionibus . . . Lipsiæ, 1817. 8vo (pp. 228 and introduction xxxviii). There is also a German titlepage. § 4.

PEACOCK (Arithmetic). § 2, art. 3.

PEARSON, W. An introduction to Practical Astronomy containing Tables . . . . London, 1824. 2 vols. Large 4to. § 4.

[PELL, J.] Tabula Numerorum Quadratorum decies millium, unà cum ipsorum lateribus ab unitate incipientibus & ordine naturali usque ad 10 000 progredientibus . . . London, 1672. 4to (pp. 32). § 3, art. 4.

PETERS, C. F. W. Astronomische Tafeln und Formeln. . . Hamburg, 1871. 8vo (pp. 217). § 4.

PEZENAS. See GARDINER (Avignon edition, 1770).

PHILLIPS, SIR THOMAS, Bart. An improved Numeration Table to facilitate and extend Astronomical Calculations . . . [London?], 1829. 12mo (pp. 18). § 3, art. 25.

PICARTE, R. La Division réduite à une Addition, ouvrage approuvé par l'Académie des Sciences de Paris . . . augmenté d'une Table de Logarithmes . . . Paris [1861]. 4to (pp. 104 and introduction &c. xvi). § 3, art. 7.

PIGRI, GIUSEPPE. Nuove Tavole degli Elementi dei Numeri dall' 1 al 10 000 . . . Pisa, 1758. 8vo (pp. 195). § 3, art. 8.

Pineto, S. Tables de Logarithmes vulgaires à dix décimales construites d'après un nouveau mode ... S.-Pétersbourg, 1871. 8vo (pp. 56 and introduction xxiv). § 3, art. 13.

Pitiscus. Thesaurus mathematicus Sive canon sinuum ad radium 1.00000.00000.00000. et ad dena quæque scrupula secunda Quadrantis: una cum sinibus primi et postremi gradus, ad eundem radium, et ad singula scrupula secunda Quadrantis: Adjunctis ubique differentiis primis et secundis; atq, ubi res tulit, etiam tertijs. jam olim quidem incredibili labore & sumptu à Georgio Joachimo Rhetico supputatus: at nunc primum in lucem editus & cum viris doctis communicatus a Bartholomæo Pitisco Grunbergensi Silesio. cujus etiam accesserunt: I. Principia Sinuum, ad radium, 1.00000. 00000.00000.00000.00000. quàm accuratissimè supputata. II. Sinus decimorum, tricesimorum & quinquagesimorum quorumq; scrupulorum secundorum per prima & postrema 35. scrupula prima, ad radium, 1.00000.00000.00000, 00000.00. [Typographical ornament.] Francofurti Excudebat Nicolaus Hoffmannus, sumptibus Jonæ Rosæ Anno CIↃ. IↃ. XIII. folio [part of the title is printed in red] (preface 5 pp., tables pp. 2–271, pp. 2–61, pp. 3–15). There are four titlepages altogether, including that to the whole work (copied above); on the first two the date should be CIↃ. IↃC. XIII, and not as printed. § 3, art. 10.

Poggendorff (Handwörterbuch). § 2, art. 3.

Prasse. See De Prasse.

Prony. See Tables du Cadastre. See also § 3, art. 13 (introductory remarks, p. 54), and § 3, art. 16 (introductory remarks, p. 69).

Rahn, J. H. Teutsche Algebra, oder Algebraische Rechenkunst ... Zurich, 1659. Very small quarto (pp. about 200). § 3, art. 8.

Rankine, W. J. M. Useful Rules and Tables relating to Mensuration, Engineering, Structures, and Machines ... London, 1866. 8vo. § 4.

Raper, Henry, Lieut. R.N. Tables of logarithms to six places ... London, 1846. 8vo (pp. 122 and introduction xi). § 4.

Raper, Henry, Lieut. R.N. The Practise of Navigation and Nautical Astronomy ... Sixth Edition. London, 1857. 8vo (454 pp. of tables). § 4.

Rees, Abraham. The Cyclopædia, or Universal Dictionary of Arts, Sciences, and Literature ... In 39 vols. London, 1819. 4to. Vol. xviii. *Hyperbolic logarithms.* § 3, art. 16. Vol. xxi. *Logarithms.* § 3, art. 13, Vol. xxviii. *Prime numbers.* § 3, art. 8.

Reishammer, Félix. Manuel général pour les Arbitrages de Changes ... par *Nombres fixes* ou par *Logarithmes* ... suivi d'une Table de Logarithmes depuis 1 jusqu'à 10400 (et, à l'aide de la Tables des Différences, jusqu'à 104000) ... Paris. An viii (1800). 8vo (pp. 326 and 131 pp. of tables). § 3, art. 13.

Requisite Tables. See [Maskelyne.]

Reuss (Repertorium). § 2, art. 3.

Reynaud, A. A. L. Trigonométrie ... troisième édition; suivie des tables de logarithmes ... de Jérôme de Lalande. Paris, 12mo, 1818 (203 pp. of tables). § 4.

Reynaud. See Lalande (1829).

Rheticus. Opus Palatinum de triangulis a Georgio Ioachimo Rhetico cœptum: L. Valentinus Otho Principis Palatini Friderici IV. Electoris mathematicus consummavit. An. sal. hum. CIↃ. IↃ. XCVI. Plin. lib. xxxvi. cap. ix. Rerum naturæ interpretationem Ægyptiorum opera philosophiæ continent. Cum privilegio cæs. majes. folio, 2 vols. [on an ornamented titlepage]. § 3, art. 10.

RHETICUS. See PITISCUS.

RIDDLE, EDWARD. Treatise on Navigation and Nautical Astronomy ... with all the Tables requisite in nautical computations ... London, 1824. 8vo (239 pp. of tables). § 4.

RILEY'S Arithmetical Tables for multiplying and dividing sums to the utmost extent of numbers ... London, 1775. 8vo (pp. 176 and introduction xii). § 3, art. 1.

RIOS, JOSEPH DE MENDOZA. A complete collection of Tables for Navigation and Nautical Astronomy ... Second edition, improved. London, 1809. 4to (604 pp. of tables). § 4.

RIOS, JOSÉ DE MENDOZA Y. Coleccion completa de Tablas para los usos de la Navegacion y Astronomia Náutica ... Primera Tirada. Madrid, 1850. 4to. § 4.

ROE, N. Tabulæ Logarithmicæ, or two tables of logarithmes ... by NATHANIEL ROE, Pastor of Benacre in Suffolke ... Unto which is annexed their admirable use ... by EDM. WINGATE, Gent. London, 1633. 8vo (preface and tables unpaged, the *Use* &c. pp. 70, and 10 addit. pp. of tables). § 4.

ROGG (Bibliotheca Mathematica). § 2, art. 3.

ROSENBERG. See DASE (ninth million).

ROUSE, WILLIAM. The Doctrine of Chances, or the Theory of Gaming made easy ... with Tables on Chance, never before published ... London [no date]. 8vo (pp. 350, preface &c. lvi). § 3, art. 25.

RUMKER, C. Handbuch der Schifffahrtskunde mit einer Sammlung von Seemanns-Tafeln ... Vierte Auflage. Hamburg, 1844. 8vo (531 pp. of tables). § 4.

SAIGEY. See under CALLET, 1853, § 4.

*SALOMON, JOS. M. Logarithmische Tafeln, enthaltend die Logarithmen der Zahlen 1–10800, die Logarithmen der Sinusse und Tangenten von Sekunde zu Sekunde, etc. Wien, 1827. 4to (pp. 466 and introduction xxxviii). Also with French text. § 4.

SANG, EDWARD. Five-place logarithms ... Edinburgh and London, 1859. 32mo (pp. 32). § 3, art. 13.

SANG, EDWARD. A new table of seven-place logarithms of all numbers from 20 000 to 200 000 ... London, 1871. Large 8vo (pp. 365). § 3, art. 13.

SANG, EDWARD. 'Edinburgh Transactions,' vol. xxvi. 1871. (Account of the new table of logarithms to 200 000). See under SANG, § 3, art. 13.

SCHEIBEL (Mathematical Bibliography). § 2, art. 3.

[SCHEUTZ, G. and E.] Specimens of Tables; calculated, stereomoulded, and printed by Machinery. London, 1857. 8vo (pp. 50). § 3, art. 13.

*SCHLÖMILCH, O. Fünfstellige logarithmische und trigonometrische Tafeln. Braunschweig. 8vo. § 4.

SCHMIDT, G. G. Logarithmische, trigonometrische und andere Tafeln ... Giessen, 1821. 12mo (pp. 217 and introduction xxii). § 4.

SCHRÖN, LUDWIG. Tafeln der drei- und fünfstelligen Logarithmen ... Jena, 1838. (Small quarto tract, without cover, 20 pp.) § 3, art. 13.

SCHRÖN, LUDWIG. Siebenstellige gemeine Logarithmen der Zahlen von 1 bis 108000 und der Sinus, Cosinus, Tangenten und Cotangenten ... nebst einer Interpolationstafel zur Berechnung der Proportionaltheile ... Stereotyp-Ausgabe. Gesammt-Ausgabe in drei Tafeln. Braunschweig, 1860. Large 8vo (pp. 550). § 4.

SCHRÖN, LUDWIG. Seven-figure logarithms ... Fifth edition, corrected and stereotyped. With a description of the tables added by A. DE MORGAN ... London and Brunswick, 1865. 8vo. § 4.

SCHULZE, JOHANN CARL. Neue und erweiterte Sammlung logarithmischer, trigonometrischer und anderer....Tafeln. Berlin, 1778. 2 vols. 8vo (each about 300 pp.). There is also a French titlepage. § 4.

SCHULZE. See ACADÉMIE ROYALE DE PRUSSE, § 4.

SCHUMACHER, H. G. Sammlung von Hülfstafeln herausgegeben im Jahre 1822 von H. G. Schumacher. Neu herausgegeben und vermehrt von G. H. L. WARNSTORFF. Altona, 1845. 8vo (pp. 221, and 31 pp. of explanation in French). § 4.

[SCHUMACHER.] Auxiliary Tables for Mr. Bessel's method of clearing the Distances. 8vo (pp. 91). [No editor's name, date, or place.] § 4.

SCHWEIGGER-SEIDEL (Litteratur der Mathematik). § 2, art. 3.

SÉGUIN, M. Manuel d'Architecture ou Principes des Opérations primitives de cet Art....Cet ouvrage est terminé par une table des quarrés et des cubes, dont les racines commencent par l'unité, et vont jusqu'à dix mille.... Paris, 1786. 8vo (the table occupies 100 pp.). § 3, art. 4.

SHANKS, WILLIAM. Contributions to Mathematics, comprising chiefly the Rectification of the Circle to 607 places of decimals... London, 1853. Printed for the Author. 8vo (pp. 95). § 4.

[SHARP, ABRAHAM.] Geometry Improv'd. 1. By a large and and accurate table of segments of circles....with compendious tables for finding a true proportional part... exemplify'd in making out Logarithms or natural numbers from them, true to sixty figures, there being a table of them for all primes to 1100, true to 61 figures. 2. A concise treatise of Polyedra.... By A. S. Philomath.... London, 1717. Small 4to (pp. 136). § 4.

SHARP. See SHERWIN.

SHEEPSHANKS, R. Tables for facilitating Astronomical Reductions. London, 1846. 4to. § 4. (Also ANONYMOUS, 1844). § 4.

[SHERWIN, HENRY.] Sherwin's Mathematical Tables, contriv'd after a most comprehensive method.... The third edition. Carefully revised and corrected by William Gardiner. London, 1741. 8vo. § 4.

SHORTREDE, ROBERT. Compendious Logarithmic Tables.... Edinburgh, 1844. 8vo (pp. 10). § 4.

SHORTREDE, ROBERT. Logarithmic Tables to seven places of decimals containing.... Edinburgh, 1844. Large 8vo (pp. 829, and introduction, pp. 39). § 4. Also 1849 (2 vols.). See next title.

SHORTREDE, ROBERT. Logarithmic Tables: containing logarithms to numbers from 1 to 120,000, numbers to logarithms from ·0 to 1·00000, to seven places of decimals; .... Edinburgh, 1849. 8vo (pp. 208 and preface xxv). This is the title of the first volume; that of the second is, "Logarithmic Tables to seven places of decimals, containing logarithmic sines and tangents to every second of the circle, with arguments in space and time ..." Edinburgh, 1858 (pp. 602 and preface pp. 2), 8vo. The two volumes seem to have been regarded as separate works, as the book is not stated to be in 2 vols; nor are they called vol. i. and vol. ii. § 4, under SHORTREDE, 1849.

SOHNKE (Bibliotheca Mathematica). § 2, art. 3.

SPEIDELL, J. New logarithmes. the First inuention whereof, was, by the Honourable Lo: Iohn Nepair Baron of Marchiston, and Printed at Edinburg in Scotland, Anno: 1614. In whose vse was and is required the knowledge of Algebraicall Addition and Subtraction, according to + and − These being Extracted from and out of them (they being first ouer seene, corrected, and amended) require not at all any skill in Algebra, or Cossike numbers, But may be vsed by euery one that can onely adde and Subtract, in whole numbers, according to the Common or vulgar Arithmeticke, without any consideration

or respect of + and — [Typographical ornament] By Iohn Speidell, professor of the Mathematickes; and are to bee solde at his dwelling house in the Fields, on the backe side of Drury Lane, betweene Princes streete and the new Playhouse. [Erasure in ink.] 1619 (unpaged, pp. 90 and titlepage). § 3, art. 16.

Stansbury, Daniel. Tables to facilitate the necessary Calculations in Nautical Astronomy....New York, 1822. 4to (337 pp. of tables). § 4.

[Stegmann, F.] Tafel der fünfstelligen Logarithmen und Antilogarithmen. Marburg, 1855. § 4.

*Stegmann. Tafel der natürlicher Logarithmen. Marburg, 1856. § 4.

Steinberger, A. Tafel der gemeinen oder Brigg'schen Logarithmen aller Zahlen von 1—1 000 000 mit fünf und beliebig sieben Decimalstellen.... Regensburg, 1840. 8vo (pp. 65). § 3, art. 13.

Tables du Cadastre, calculated under the direction of Prony (manuscript). § 3, art. 13.

Taylor, Janet. Lunisolar and Horary Tables, with their application in Nautical Astronomy.... London, 1833. 8vo (pp. 232). § 4.

Taylor, Janet. An Epitome of Navigation and Nautical Astronomy, with the improved Lunar Tables.... London, 1843. 8vo (320 pp. of tables). § 4.

Taylor, Michael. A Sexagesimal Table....and the Sexagesimal Table turned into seconds as far as the 1000th column.... Published by order of the Commissioners of Longitude. London, 1780. 4to (pp. 316 and introduction xlv) § 3, art. 9.

Taylor, Michael. Tables of logarithms of All numbers, from 1 to 101000, and of the sines and tangents to every second of the quadrant.... With a preface....by Nevil Maskelyne.... London, 1792. Large 4to (about 600 pp.). § 4.

Templeton, W. The Millwright and Engineer's pocket Companion ... corrected by Samuel Maynard: London, 1871. 8vo. (Noticed under [Maynard], § 3, art. 24).

Thomson, David. Lunar and Horary Tables.... Forty-fourth edition. London, 1852. 8vo (218 pp. of tables). § 4.

Todd, Charles. A series of Tables of the Area and Circumference of Circles; the Solidity and Superficies of Spheres; the Area and Length of the Diagonal of Squares.... Second edition. London, 1853. 8vo (pp. 114). § 3, art. 22.

Trotter, James. A Manual of Logarithms and Practical Mathematics.... Edinburgh, 1841. 8vo (82 pp. of tables). § 4.

Turkish Table of Logarithms &c. [Búlák] 1250 [1834]. 8vo (pp. 270). § 4.

Ursin. See G. F. Ursinus.

Ursinus, B. Beni. Ursini Mathematici Electoralis Brandenburgici Trigonometria cum magno logarithmor. Canone Cum Privilegio Coloniæ Sumptib. M. Guttij. tipijs G. Rungij descripta CD DCXXV (*sic*). (This is the title of the volume, and is printed on an ornamented titlepage.) The *trigonometria* occupies 272 pp.; and then follows the *Canon*, unpaged, with a fresh titlepage. "Benjaminis Ursini Spottavi Silesi .... Magnus Canon triangulorum logarithmicus; ex voto & consilio Illustr. Neperi, p. m. novissimo, Et sinu toto 100000000. ad scrupulor. secundor. decadas usq; vigili studio & pertinaci industriâ diductus ... Coloniæ. Typis Georgij Rungij ... M.DC.XXIV"; but the colophon (at the end of the canon and of the whole work) is "Berolini, Excudebat Georgius Rungius Typographus, impensis & sumtibus

Martini Guttij. Bibliopolæ Coloniensis. Anno CIϽ IϽC XXIV." 4to. § 3, art. 17.

URSINUS, G. F. Logarithmi VI Decimalium scilicet numerorum ab 1 ad 100 000 et Sinuum et Tangentium ad 10″ . . . (Impensis autoris.) Hafniæ, 1827. 8vo. § 4.

VEGA, G. Thesaurus logarithmorum completus, ex arithmetica logarithmica, et ex trigonometria artificiali Adriani Vlacci collectus, plurimis erroribus purgatus, in novum ordinem redactus, ... Wolframii denique tabula logarithmorum naturalium locupletatus a Georgio Vega . . . . Lipsiæ, 1794. folio (pp. 685 and introduction xxx). There is also a German titlepage. § 4.

VEGA, G. Georgii Vega . . . . tabulæ logarithmico-trigonometricæ cum diversis aliis in Matheseos usum constructis Tabulis et Formulis. . . . Editio secunda, emendata, aucta penitusque reformata. Lipsiæ, 1797. 2 vols. 8vo (pp. 409 and 371; vol. i. has also lxxxiv pp. introduction). There is also a German titlepage. § 4.

VEGA, G. Georgii Vega. . . . manuale logarithmico-trigonometricum. . . . Editio secunda, aucta et emendata. Lipsiæ, 1800. 8vo (pp. 304 and introduction lxiv). There is also a German titlepage. § 4.

VEGA, G. Sammlung mathematischer Tafeln. . . . Herausgegeben von Dr. J. A. HÜLSSE. Stereotyp-Ausgabe. Erster Abdruck. Leipzig, 1840. 8vo (pp. 681 and introduction xxiv). § 4 (described as HULSSE's VEGA).

VEGA, G. Logarithmisch-trigonometrisches Handbuch (einundvierzigste Auflage). . . . bearbeitet von Dr. C. BREMIKER. Berlin, 1857. 8vo (pp. 575 and introduction xxxii). § 4 (described as BREMIKER's VEGA).

VEGA, G. Logarithmic Tables. . . . by Baron von Vega, translated from the fortieth edition of Dr. Bremiker's by W. L. F. FISCHER. . . . Thoroughly revised and enlarged edition . . . . Stereotyped . . . . Berlin, 1857. (pp. 575 and introduction xxvii) § 4 (under BREMIKER's VEGA).

VERSED SINES, A Table of. See [SIR JONAS MOORE.]

VERSED SINES, Natural . . . and Logarithmic . . . See [FARLEY].

VLACQ, ADRIAN. Arithmetica logarithmica, sive logarithmorum chiliades centum, pro Numeris naturali serie crescentibus ab Unitate ad 100000. una cum canone triangulorum seu tabula artificialium Sinuum, Tangentium, & Secantium, Ad Radium 10,00000,00000. & ad singula Scrupula Prima Quadrantis. Quibus novum traditur compendium, quo nullum nec admirabilius, nec utilius solvendi pleraque Problemata Arithmetica & Geometrica. Hos numeros primus invenit Clarissimus Vir Iohannes Neperus Baro Merchistonij: eos autem ex ejusdem sententiâ mutavit, eorumque ortum & usum illustravit Henricus Briggius, in celeberrimâ Academiâ Oxoniensi Geometriæ Professor Savilianus. Editio Secunda aucta per Adrianum Vlacq Goudanum. Deus nobis usuram vitæ dedit et ingenii, tanquam pecuniæ, nulla præstituta die. [Typographical ornament.] Goudæ, Excudebat Petrus Rammasenius. M.DC.XXVIII. Cum Privilegio Illust. Ord. Generalium. fol. (preface and errata 5 pp., trigonometry &c. 79 pp.; tables unpaged). Part of the title is printed in red. § 4.

VLACQ, ADRIAN. Arithmetique logarithmique ou la construction et usage d'une table contenant les Logarithmes de tous les Nombres depuis l'Unité jusques à 100000. et d'une autre table en laquelle sont comprins les Logarithmes des Sinus, Tangentes & Secantes, de tous les Degrez & Minutes du quart du Cercle, selon le Raid de 10,00000,00000. parties. Par le moyen desquelles on resoult tres-facilement les Problemes Arithmetiques & Geometriques. Ces nombres premierement sont inventez par Iean Neper Baron de Marchiston: mais Henry Brigs Professeur de la Geometrie en l'Université

d'Oxford, les a changé, & leur Nature, Origine, & Usage illustré selon l'intention du dit Neper. La description est traduite du Latin en François, la premiere Table augmentée, & la seconde composée par Adriaen Vlacq. Dieu nous a donné l'usage de la vie et d'entendement, plus qu'il n'a fait par le temps passé. [Small typographical ornament]. A Goude, Chez Pierre Rammasein. M.DC.XXVIII. Avec Privilege des Estats Generaux. fol. (preface 3 pp., errata 1 p., trigonometry &c. 84 pp.; tables unpaged). Part of the title is printed in red. § 4.

[The radius is erroneously described in the above two titles as 10,00000,00000; it is really 1,00000,00000, viz. the logarithms are given to ten decimal places.]

VLACQ, ADRIAN. Logarithmicall arithmetike. or tables of logarithmes for absolute numbers from an unite to 100000; as also for Sines, Tangentes and Secantes for every Minute of a Quadrant: with a plaine description of their use in Arithmetike, Geometrie, Geographie, Astronomie, Navigation, &c. These Numbers were first invented by the most excellent Iohn Neper Baron of Marchiston, and the same were transformed, and the foundation and use of them illustrated with his approbation by Henry Briggs Sir Henry Savils Professor of Geometrie in the Universitie of Oxford. The uses whereof were written in Latin by the Author himselfe, and since his death published in English by diverse of his friends according to his mind, for the benefit of such as understand not the Latin tongue. Deus nobis usuram vitæ dedit, et ingenii, tanquam pecuniæ, nulla præstituta die. [Printer's device and motto, Anchora spei.] London, Printed by George Miller. 1631. fol. (54 pp. of trigonometry &c. followed by "a Table of Latitudes" (8 pp.), and then the logarithmic tables, unpaged). § 4.

VLACQ, ADRIAN. Trigonometria artificialis: sive magnus canon triangulorum logarithmicus, Ad Radium 100000,00000, & ad dena Scrupula Secunda, ab Adriano Vlacco Goudano Constructus. Cui Accedunt Henrici Briggii Geometriæ Professoris in Academiâ Oxoniensi P.M. Chiliades logarithmorum Viginti pro numeris naturali serie crescentibus ab Unitate ad 20000. Quorum ope triangula plana & sphærica, inter alia Nova eximiaque compendia è Geometricis fundamentis petita, solâ Additione, Subtractione, & Bipartitione, exquisitissimè dimetiuntur. [Here follows a quotation of seven lines from Kepler. Harm. lib. iv. cap. vii. p. 168.] Goudæ, Excudebat Petrus Rammasenius. Anno M.DC.XXXIII. Cum Previlegio. folio. (Dedication and preface 4 pp., trigonometry &c. 52 pp.; tables unpaged). § 4.

VLACQ, ADRIAN. Tabulæ sinuum, tangentium et logarithmi sinuum tangentium & numerorum ab unitate in 10,000.... Editio ultima emendata & aucta. Amstelædami: Apud Henricum & Viduam Theodori Boom. 1681. Small 8vo. § 4.

VLACQ's works (Chinese reprint). § 3, art. 13 (introductory remarks, p. 54).

VLACQ. See HENTSCHEN.

*VOISIN, ANTOINE. Tables de Multiplications ou Logarithmes des Nombres Entiers depuis 1 jusqu'à 20,000.... Paris, 1817. § 3, art. 3.

WACKERBARTH, A. F. D. Fem-ställiga Logarithm-Tabeller, jemte en Samling Tabeller.... Upsala, 1867. Small 8vo (pp. 224 and introduction xviii). § 4.

WALLACE, JOHN. Mathematical Tables containing the logarithms of numbers, logarithmic sines, tangents, and secants.... By J. BROWN. The third edition, improved, enlarged with many useful additions, by J. WALLACE. Edinburgh, 1815. 8vo. § 4.

WALLIS. See SHERWIN.

WARNSTORFF. See SCHUMACHER.

WEIDENBACH. Tafel um den Logarithmen von $\frac{x+1}{x-1}$ zu finden wenn der Logarithme von x gegeben ist.... Mit einem Vorworte von Herrn Hofrath GAUSS. Copenhagen, 1829. 16mo (pp. 24). § 3, art. 19.

WELLS, I. Sciographia. London, 1635. See under DE DECKER, 1626.

WILLICH, C. M. Popular Tables arranged in a new form.... Third edition. London, 1853. 8vo (pp. 166). § 4.

WINGATE. See ROE.

WITTSTEIN, THEODOR. Logarithmes de Gauss à sept décimales.... Hannover, 1866. 8vo (pp. 127 and introduction xvi). § 3, art. 19.

WOLFRAM. 48-place hyperbolic logarithms: these first appeared in SCHULZE's Sammlung. See SCHULZE (1778).

WOOLHOUSE, W. S. B. On Interpolation, Summation, and the Adjustment of Numerical Tables.... London, 1865. 8vo (pp. 100). § 3, art. 21.

WOOLHOUSE. See OLINTHUS GREGORY (1843).

WUCHERER, W. F. Beyträge zum allgemeinern Gebrauch der Decimal-Brüche.... Carlsruhe, 1796. 8vo (152 pp. of tables and 48 pp. of introduction). § 3, art. 6.

ZECH, J. Tafeln der Additions- und Subtractionslogarithmen für sieben Stellen....Aus der Vega-Hülsse'schen Sammlung besonders abgedruckt. Leipzig, 1849. 8vo (pp. 201). Also "Zweiter Auflage," 1863. § 3, art. 19.

§ 6. *Postscript.*

Art. 1. The foregoing Report is that which was presented to the Brighton Meeting in 1872, considerably enlarged. After the Meeting it seemed desirable to extend some of the articles in § 3, and to add descriptions of several works to § 4; and it then appeared that the Report was so lengthy that it was thought better to delay its publication till the ensuing volume, so as to afford time for its passage through the press without undue haste. The printing therefore was commenced in February or March, and is now (September 30, 1873) all but finished. It was arranged, as the completion of the Report by a supplement depended in great measure on the cooperation of others possessing information on the subject of tables, that a certain number of separate copies should be placed in the hands of the Committee, as soon as the printing was effected, for circulation amongst those interested in the matter, so as to avoid the delay of a year that would otherwise take place before the work undertaken by the Committee became known to those who could render assistance.

Art. 2. While the Report has been passing through the press a good many alterations have been made which were necessitated by increased information on the subjects treated of, and by repetitions &c. which were detected for the first time when the whole appeared in print. But no attempt has been made to increase the extent of the Report by introducing descriptions of fresh works; in fact only about a dozen have been added since the Brighton Meeting, and but four or five since the MS. was placed in the printer's hands.

The tendency of the Report has been from the first to become more and more bibliographical. Originally it was intended to introduce nothing of a bibliographical nature; but experience showed that this was impossible, and attention to such matters has been continually forced upon us. A report on tables differs from a report on any other scientific subject in this—that whereas in a progressive science the earlier works become superseded by

their successors, and are only of historical interest, a table forms a piece of *work done*, and, if done correctly, is done for all time. Thus Briggs, 1624, or Vlacq, 1628, when procured, are as useful now as if the tables had been calculated and published recently, subject to the one drawback, that it needs a bibliographical research to determine how far their accuracy is to be relied upon. A table is calculated for a special purpose, which purpose in process of time ceases to be an object of practical interest, and the table is forgotten; but, for all that, it is the expression of a certain amount of abstract truth, and as such is always of value, and is liable at any moment to be utilized again for some other purpose. Thus one of the most useful objects of the Report is to give in an accessible form accounts of old tables that have passed out of notice, as even the most special table is never so obsolete that some fresh use may not be found for it in the future; and it is of little value to describe an old and unimportant work without such additional explanation as may lead to its easy identification, with references to the works that contain information of importance to its user.

Art. 3. But, apart from the necessity of giving bibliographical information with regard to some works in order to render the descriptions useful, it is to be noticed that mathematical history is practically nothing but mathematical bibliography, as the number of letters and other manuscript documents bearing upon the subject is very small. This being so, it seemed a pity when the examination of any work showed it to possess some interest, even though of a purely historical kind, to ignore it entirely merely because the table it contained was clearly destitute of practical value*. The whole additional space thus devoted to bibliography does not altogether amount to more than a very few pages; and the chief concession that has been made to it is in the list of titles in § 5, where in several cases the full titlepage has been transcribed. This, with one or two exceptions, has only been done in the case of the tables of logarithms immediately following their invention in 1614. An examination of a great number of works of reference in regard to this matter has shown us how inaccurate, not only in details but even in prominent facts, are the accounts usually given. With the exception of Delambre, Lalande (in his 'Bibliographie Astronomique'), and De Morgan, it is not too much to say that not a single writer on the subject is to be trusted. Those only who have had occasion to investigate any historical point, like that of the invention of logarithms, can appreciate the slight value that was set on accuracy previously to the dawning of a more careful age at the beginning of the present century. It is necessary to give this caution, as any one who took the trouble to compare certain statements made in this Report with those given in such works as Thomson's 'History of the Royal Society,' or even Hallam's 'Literature of Europe' (founded on earlier works), might imagine that our account involved matters of opinion and was liable to be disputed; whereas we cannot find that any previous writer ever did (or perhaps could in the then state of libraries) examine or even see *all* the works relating to this period. It is also worthy of remark that the early logarithmic tables form a most remarkable bibliographical tangle. For some years it was customary to always place the name of Napier on the titlepages

* "It would be something towards a complete collection of mathematical bibliography, if those who have occasion to examine old works, and take a pleasure in doing it, would add each his quotum, in the shape of description of such works as he has actually seen, without any attempt to appear more learned than his opportunities have made him."—De Morgan, 'Arithmetical Books,' p. x. See also 'Companion to the Almanac,' 1851, p. 5.

of works on logarithms, as being their inventor, and, if the logarithms were decimal, that of Briggs (and perhaps also that of Vlacq) in addition. Thus the 'Arithmetica' of 1628 will be found in bibliographies and library catalogues usually under the name of Napier or Briggs, and very rarely under that of its author Vlacq. If to this confusion be added the additional complication produced by the varieties of ways in which the names of the three leading logarithmic calculators were spelt, it may easily be inferred how incorrect and confused is all the information to be obtained from bibliographical sources, whether general or mathematical*. It is on this account that we have thought it desirable to give the titles of these works in full in § 5. Perhaps it would not have been possible to see so many of them in any one other country except this; and the value of a number of such titles collectively in the same list is much greater than the sum of their separate values when scattered in different works.

Art. 4. While on the subject of bibliography, it is proper to remark that, in the cases where the full titles have been given in § 5, there is a certain slight want of uniformity in the way in which they have been transcribed, viz. in the use of capitals, the writing at full length of words abbreviated, and the modernizing the language by the substitution of u for v or i for j, and *vice versâ*. Titlepages are printed partly in capital and partly in Roman and italic characters; and when they are transcribed wholly in Roman letters, there arise several uncertainties. Thus it is usual in the portion printed in capitals to replace U by V and J by I, and very often not to use a larger letter after a full stop or for a proper name; and in copying the whole in Roman letters it is doubtful whether to write these as they are, or to reconvert them. We are inclined to think that the best plan (except when capitals are reprinted as capitals &c., in which case no difficulty occurs) is to make an exact copy, and not even introduce a capital letter after a full stop, although the author would no doubt have done so himself had he printed his titlepage in Roman characters throughout. Exception must, however, be made in the case of proper names. These rules have not been followed out completely in one or two of the earliest titles that we copied, before experience had taught us that in bibliographical matters the greatest attainable accuracy should be invariably striven after; also one or two abbreviations have been replaced by the words at length (such as *e. g.* "serenis^{mi}" by "serenissimi" or "atq;" by "atque"). Whenever, of course, any difference from ordinary spelling is observed, it may be taken for granted that the title is so printed in the book; the utmost change that has been made being that some words in a few of the titles are modernized.

The foregoing remarks apply to the titles that are transcribed at length; but a few words must also be said with regard to those in which only enough is given to identify the books described without possibility of mistake. Wherever words are left out from the title, the omission is marked

* Even Babbage makes a bibliographical error on the first page of the preface to his tables, where he says that "the first 20,000 were read with those in the Trigonometria Artificialis of Briggs." The 'Trigonometria Artificialis' was calculated by Vlacq, and published by him two years after Briggs's death, though the 20,000 logarithms appended were of course originally computed by Briggs. Any one who will look at the title of the 'Trigonometria Artificialis' in § 5 will see how easily a mistake of this kind can be made; and in fact an inspection of the titles of the other works of this period will show that it would be difficult for any one who had not bestowed some attention on the history of logarithms to assign them to their true authors. Part of the confusion that exists is due to Vlacq's excessive modesty, which led him on the titlepages of his works to give quite a subordinate position to his own name compared with those of Napier and Briggs.

by dots, except between place and date, where the publisher's name almost invariably occurs; so that, this being understood, the separation by a comma was considered sufficient. If the work of the Report had to be performed over again, we should adopt a set of fixed rules with regard to the use of initial capitals in the printing of words in titles, instead of leaving the matter to caprice or the printer; as it is, the treatment in this respect has been fairly uniform, but might have been better. Such details may seem insignificant; but it is desirable that nothing should be regarded as arbitrary. With regard to the number of pages assigned to books in § 5, there is also a certain want of uniformity: at first we merely looked at the number on the last page, and (having assured ourselves that the pagination was continuous) regarded that as the number of pages, ignoring the few pages at the beginning (usually with a roman pagination) that are devoted to preface &c.; but afterwards we included these also. Our object merely was to give an idea of the size of the work; so that (except in the cases where the interest of the book was bibliographical, when we took pains to be quite accurate) it was not thought necessary always to count pages that were not numbered. Sometimes it seemed desirable to give the number of pages occupied by the tables instead of the number in the whole book; and in a few cases, where the pages were not numbered, it was not considered worth while to count them, or even give an estimate. It may be remarked that very frequently (we think we might say more often than not) the pages on which extensive tabular matter is printed are not numbered.

Art. 5. The distinction mentioned in § 2, art. 8, between works that are and works that are not described in the Report, viz. that the names of the authors of the former, when the works are referred to, are printed in small capitals, and of the latter in roman characters, has been adhered to as carefully as possible; but it has been found to be very troublesome and unsatisfactory. We have generally thought it sufficient to print the name in small capitals only once in a paragraph; and when there is no risk of mistake (as in the description of the work in question itself) the name has been printed in ordinary roman type: the distinction will not be retained in future Reports.

Also, with reference to the meanings to be attached to the words 8vo, 4to, &c., explained in § 2, art. 9, experience has shown that it is more convenient to use these terms in their technical significations, viz. as defined by the number of pages to the sheet; and in future Reports they will be so used. It should be stated that, except in the case of a few books of no bibliographical interest, these have been the meanings actually adopted. Care was taken that this should be so in regard to all works of bibliographical interest; and in most other cases the size, as estimated by the eye, agrees with the technical signification.

Art. 6. In § 1 it is stated that the Committee had determined to print and stereotype certain tables of e^x and e^{-x}, and of hyperbolic sines and cosines which had been commenced by the reporter, and that they were then in the press. Only four pages were set up when the above statement was written; and shortly afterwards, when the elliptic functions (referred to further on in art. 16) were in process of calculation, it became clear that they would occupy so much attention that it was not likely that the tables of e^x &c. could be continued by the reporter till after their completion, and, further, that the publication of the elliptic functions would tax the resources of the Committee to such an extent that it was not probable that they would have the means of printing any thing else, at all events for some time. These tables were therefore withdrawn; and the reporter contemplates completing

them (very little more remains to be done) after the publication of the elliptic functions, when they will probably be communicated to one of the learned societies. The table of powers by the reporter, mentioned in § 3, art. 5, is entirely completed, except for the final verification by differences, which is in progress; and the printing will be commenced very shortly; but as it is intended to prefix to it a list of constants, with historical notices of the calculation of each, the publication may be somewhat delayed.

Art. 7. Any one who studies the Report attentively cannot fail to notice differences of modes of description in it. These are only verbal, and will be seen to be unavoidable when it is considered that, as a rule, the account of each book was written by itself on a separate piece of paper, and that not till all had been arranged, and the Report was in print, was it easy to compare the descriptions of the same table occurring in different works, and therefore written under different circumstances. Very few of these "discrepancies" have been removed, partly because, as each description was correct, it seemed scarcely worth while to make alterations for the sake of a fictitious uniformity, and partly because we made it a rule that, a description having been written in the presence of the book, it ought not to be altered when the book was absent. Slight differences of style and manner are inevitable in a work the performance of which has extended over the space of two years, as experience must always continually modify to some extent both opinions and modes of thought and expression; of course, if the work could be done over again with the experience already obtained, the descriptions would be more uniform.

Art. 8. An objection might be made on the ground that descriptions are given of some very minor works, which have not even the bibliographical interest due to age. In answer to this it is to be noted (1) that it is sometimes as important to know that a book does not contain any thing of value as to know what is in it if it does, and that the reader alone should be left to decide what is and what is not valuable; and (2) that no book is so insignificant that in the future a correct account of its contents will not be of value. "The most worthless book of a bygone day is a record worthy of preservation. Like a telescopic star, its obscurity may render it unavailable for most purposes; but it serves, in hands which know how to use it, to determine the places of more important bodies" (De Morgan, 'Arithmetical Books,' page ii). Although the primary object of the Report is utility in the present, still it is not desirable to entirely forget the wants of the future. The difficulty the historian of science meets with consists not so much in getting a sight of the books the existence of which he knows, as in finding out the names of the second- and third-rate authors of the period he is concerned with. Bibliographies grow more valuable as they increase in age; and it may be predicted with confidence, that long after every vestige of claim to represent the "state of science" has passed away from this Report, the list of names in § 5 will be consulted as a useful record of nineteenth-century authors of tables. It might be thought that a less detailed description of unimportant books would suffice; but it is only necessary to point out in reply, that work, unless done thoroughly, had better be left alone. An account of all the tables in a book is absolute, whereas an account only of those that seem to the writer worth notice is relative. Want of thoroughness is the thing most to be dreaded in all work of a bibliographical, historical, or descriptive nature. It is this want that renders all but valueless the greater part of seventeenth and eighteenth-century writings of this class; and any one who performs such work in an incomplete or slovenly

manner, merely accumulates obstructions which obscure the truth, and renders more difficult the task of his successors, who will have to be at the pains not only of doing the work again *de novo*, but also of correcting the errors into which others have fallen through his imperfect accounts.

Art. 9. With regard to the future Report on the subject of general tables that has been mentioned more than once, and is intended to be supplementary to the foregoing, it may be stated that a number of additional tables have already been described and will be included in it; but the cooperation of others in the matter is requested. Whether the descriptions in the Supplement will resemble those in this Report will of course depend on the extent of the former, as, if the number of works described be large, it may be necessary to practise some curtailment.

It is requested also that notices of errors detected in the Report may be sent to the reporter (see p. 12).

Art. 10. Although, as already stated, this Report has no pretensions to completeness, still any one who notices the non-appearance of names well known in calculation (such as that of Legendre) is asked to read the conclusion of § 1, the list of articles in § 3, and enough of the introductory matter in § 2 to comprehend clearly the spirit that has directed the selection of works included, before coming to the conclusion that the omission was not intentional. Books such as Legendre's 'Fonctions Elliptiques' and Jacobi's 'Canon Arithmeticus,' though forming separate publications, yet belong more properly to a later portion of the Committee's work, as they are conclusive, not subsidiary tables; the former belongs to Division II., and the latter to Division III. (see § 1, p. 4).

It is perhaps worth noting explicitly, that the word *Report* has sometimes been used to donote the whole Report that is contemplated by the Committee, including the accounts of the Integral and Theory-of-Number tables, and sometimes only the portion of it that will form one year's instalment; but the context always shows, without risk of confusion, the meaning to be assigned.

Art. 11. It was originally intended that the list in § 5 should merely contain the titles of the books described in §§ 3 and 4, with references to the section and article where each description was given. But it has been found convenient to render it in addition more of an index to the whole Report by adding cross references, and also a few titles of papers often referred to, as well as references to the places where certain other works or tracts (besides books of tables) were noticed. One or two remarks that should have appeared in the accounts of the works themselves in §§ 3 and 4 have been added after their titles in § 5 (see Babbage, Norie, 1844, and Napier, 1619, in § 5).

A table of contents is given at the conclusion of this postscript. Whether a work of reference ever gets into use or not depends more on the completeness with which it is indexed than on any thing else.

Art. 12. The following statistics will not be found without interest. The number of separate books of tables described at length in this Report (exclusive of different editions and of works only noticed incidentally) is 235, of which only 5 are derived from second-hand sources. The 230 that have thus come under the eye of the reporter are thus distributed among the different countries:—

Great Britain and Ireland	109	France	27
Germany (including Austria &c.)	66	Holland..................	8

Denmark	7	Portugal	1
Italy	3	Sweden	1
United States	3	Russia	1
Switzerland	2	Egypt	1
Spain	1		

Belgium supplying none. These figures afford no comparison between Great Britain and other countries; but they give a fair idea of the relative table-publication of foreign countries, or, at all events, of the relative proportions in which their tabular works are to be found in English libraries. The numbers of tables published in some of the chief towns are as follows:—London 94, Paris 23, Berlin 18, Leipzig 17, Edinburgh 11, Vienna 5, Copenhagen 4, New York 3. Of the 109 works published in Great Britain and Ireland the following is the distribution:—England 96 (London 94, Boston 1, Cirencester 1), Scotland 12 (Edinburgh 11, Glasgow 1), Ireland 1 (Dublin), showing the paramount position of London in the publishing trade in this country.

Art. 13. Contents of the Report that was intended to be presented to the Bradford Meeting, 1873.—Owing to the great amount of space already occupied in the present volume by the foregoing Report, it seemed desirable to postpone for a year the Report which it was till recently intended should be presented to the Bradford Meeting, and only to give here a brief description of the work performed in 1872–1873. This latter Report (which is not lengthy) consists of three parts—(1) Tables of the Legendrian Functions; (2) List of errors in Vlacq's 'Arithmetica Logarithmica,' 1628 or 1631; (3) Account of the tabulation of the Elliptic Functions.

Art. 14. *The Tables of the Legendrian Functions (Laplace's Coefficients).*—These give $P^n(x)$ to $n=7$ from $x=0$ to $x=1$ at intervals of ·01, viz. the functions are:—

$$
\begin{aligned}
P^0 &= 1,\\
P^1 &= x,\\
P^2 &= \tfrac{1}{2}(3x^2-1),\\
P^3 &= \tfrac{1}{2}(5x^3-3x),\\
P^4 &= \tfrac{1}{8}(35x^4-30x^2+3),\\
P^5 &= \tfrac{1}{8}(63x^5-70x^3+15x),\\
P^6 &= \tfrac{1}{16}(231x^6-315x^4+105x^2-5),\\
P^7 &= \tfrac{1}{16}(429x^7-693x^5+315x^3-35x);
\end{aligned}
$$

and as only powers of 2 appear in the denominators, all the decimals terminate, and their accurate values are therefore given. The work was performed in duplicate—one calculation having been made by Mr. W. Barrett Davis, and the other under the direction of the reporter, by whom the two were compared, the errors corrected, and the whole differenced. As the accurate values of the functions were tabulated, the verification by differences was absolute. A short introduction on the use of the tables in interpolation was written by Prof. Cayley, who has also made drawings of the curves $y=P^n(x)$ over the portion calculated.

Art. 15. *The List of Errors in Vlacq's 'Arithmetica Logarithmica' (1628 or 1631).*—It seemed very desirable that a complete list of the errata in Vlacq, 1628 or 1631, should be formed for the convenience of those who have occasion to employ ten-figure logarithms. No less than five copies of this work have been continually in use in the calculation of the Elliptic

Functions (see next article) during the last year; and it is the ten-figure table chiefly used. Besides this, the errata in VLACQ are known with more certainty than are those in VEGA, 1794.

This list had only been partially formed when it was determined to postpone the Report; and it is believed that the year's delay may possibly result in its being made more complete. It is proposed to add a list of errata also in DODSON's 'Antilogarithmic Canon,' 1742 (§ 3, art. 14), and perhaps to consider the subject of errors in tables generally.

Art. 16. *The account of the Tabulation of the Elliptic Functions.*—In September 1872 it was resolved to undertake the systematic tabulation of the Elliptic Functions (inverse to the Elliptic Integrals), or, more strictly, of the Jacobian Theta Functions which form their numerators and denominators.

The formulæ are:—

$$\Theta\frac{2Kx}{\pi}=1-2q\cos 2x+2q^4\cos 4x-2q^9\cos 6x+\ldots,$$

$$\Theta_1\frac{2Kx}{\pi}=\frac{1}{k^{\frac{1}{2}}}H\frac{2Kx}{\pi}$$

$$=\frac{1}{k^{\frac{1}{2}}}\left(2q^{\frac{1}{4}}\sin x-2q^{\frac{9}{4}}\sin 3x+2q^{\frac{25}{4}}\sin 5x-\ldots\right),$$

$$\Theta_2\frac{2Kx}{\pi}=\left(\frac{k'}{k}\right)^{\frac{1}{2}}H\frac{2K}{\pi}\left(x+\frac{\pi}{2}\right)$$

$$=\left(\frac{k'}{k}\right)^{\frac{1}{2}}(2q^{\frac{1}{4}}\cos x+2q^{\frac{9}{4}}\cos 3x+2q^{\frac{25}{4}}\cos 5x+\ldots),$$

$$\Theta_3\frac{2Kx}{\pi}=k'^{\frac{1}{2}}\Theta\frac{2K}{\pi}\left(x+\frac{\pi}{2}\right)$$

$$=k'^{\frac{1}{2}}(1+2q\cos 2x+2q^4\cos 4x+2q^9\cos 6x+\ldots);$$

so that

$$\sin\operatorname{am}\frac{2Kx}{\pi}=\Theta_1\frac{2Kx}{\pi}\div\Theta\frac{2Kx}{\pi},$$

$$\cos\operatorname{am}\frac{2Kx}{\pi}=\Theta_2\frac{2Kx}{\pi}\div\Theta\frac{2Kx}{\pi},$$

$$\Delta\operatorname{am}\frac{2Kx}{\pi}=\Theta_3\frac{2Kx}{\pi}\div\Theta\frac{2Kx}{\pi},$$

q being, as always, $e^{-\frac{\pi K'}{K}}$; and the tables, when completed, will give Θ, Θ_1, Θ_2, Θ_3 and their logarithms to eight decimals for

$$x=1°,\ 2°,\ldots 90°,\ k=\sin 1°,\ \sin 2°,\ldots\sin 90°.$$

The tables are thus of double entry, and contain eight tabular results for each of 8100 arguments, viz. 64,800 tabular results. The arrangement will be so that over each page k shall be constant; and at the top of each page certain constants (*i. e.* quantities independent of x), such as

$$K,\ K',\ J,\ J',\ E,\ k^{\frac{1}{2}},\ \left(\frac{k}{k'}\right)^{\frac{1}{2}},\ \left(\frac{1}{k'}\right)^{\frac{1}{2}},\ q,\ \&c.,$$

and their logarithms, which are likely to be wanted in connexion with the tables, will be added. K and K′ (complete elliptic integrals) were, as is well known, tabulated by Legendre, and published by him in 1826.

For the performance of the calculation of Θ and Θ_3 (Θ_3 being deduced from Θ) 8500 forms were printed and bound up into 15 books (550 in each, with a few over). Each book, therefore, contains forms for the calculation of six nineties, viz. from $k=\sin a^\circ$ (say), $x=0^\circ$, to $k=\sin(a^\circ+5^\circ)$, $x=90^\circ$. Similar forms for the calculation of Θ_1 and Θ_2 were printed and bound up into 15 other books.

The work has been in active progress since the beginning of October 1872; and eight computers have been engaged from that time to the present, under the superintendence of Mr. James Glaisher, F.R.S., and the Reporter. About three quarters of the work is now performed—Θ having been calculated completely, and its accuracy verified by differences, and Θ_3 being nearly finished also, while very considerable progress has been made with Θ_1 and Θ_2.

It is intended that the tables, which will be completed, it is hoped, by February 1874, shall form a separate work, and that they shall be preceded by an introduction, in which all the members of the Committee will take part, —an account of the application of the functions in mathematics generally being undertaken by Professor Cayley, of their application in the theory of numbers by Professor H. J. S. Smith, and of their use in physics by Sir W. Thomson and Professor Stokes, while the account of the method of calculation &c. will be written by the Reporter.

The magnitude of the numerical work performed has not often been exceeded since the original calculation of logarithms by Briggs and Vlacq, 1617–1628; and it is believed that the value of the tables will be great.

After the circular and logarithmic functions there are no transcendants more widely used in analysis than the Elliptic Functions; and the tables will not only render the subjects in which they occur more complete, but will also, to a great extent, render available for practical purposes a vast and fertile region of analysis. Apart from their interest and utility in a mathematical point of view, one of the most valuable uses of numerical tables is that they connect mathematics and physics, and enable the extension of the former to bear fruit practically in aiding the advance of the latter.

Art. 17. Note on the Centesimal Division of the Degree.—In the note on p. 64 we have expressed an opinion that Briggs and his followers, by dividing centesimally the old nonagesimal degree, showed a truer appreciation of how far improvement was practicable, or indeed desirable, than did the French mathematicians who divided the quadrant centesimally. On reading Stevinus's 'La Disme,' the celebrated tract in which the invention of decimal fractions was first announced, we found that the centesimal division of the degree was there suggested. The following extract from 'La Disme' is taken from pp. 156 and 157 of 'La Pratique d'Arithmetique de Simon Stevin de Bruges' (Leyden, 1585), near the end of which 'La Disme' appears in French. The first publication of the tract, as far as we can find, was in Dutch, under the title "De Thiende. . . . Beschreven door Simon Stevin van Brugghe" (Leyden, 1585).

"Article V. Des Computations Astronomiques.—Aians les anciens Astronomes parti le circle en 360 degrez, ils voioient que les computations Astronomiques d'icelles, auec leurs partitions, estoient trop labourieuses, pourtant ils ont parti chasque degré en certaines parties, & les mesmes autrefois en autant, &c., à fin de pouuoir par ainsi tousiours operer par nombres entiers, en choissisans la soixantiesme progression, parce que 60 est nombre mesurable

par plusienrs (*sic*) mesures entieres, à sçauoir 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, mais si l'on peut croire l'experience (ce que nous disons par toute reuerence de la venerable antiquité & esmeu auec l'vlilité commune) certes la soixantiesme progression n'estoit pas la plus commode, au moins entre celles qui consistoient potentiellement en la nature, ains la dixiesme qui est telle : Nous nommons les 360 degrez aussi *Commencemens* les denotans ainsi 360(0) * & chascun degré ou 1(0) se diuisera en 10 parties egales, desquelles chascune fera 1(1), puis chasque 1(1) en 10(2), & ainsi des autres, comme le semblable est faict par plusieurs fois ci deuant " †.

At the end of the 'Appendice du Traicté des Triangles,' which concludes the fourth book of the "Cosmographie" in Albert Girard's edition of Stevinus's collected works, Leyden, 1634 (p. 95), there occurs the following note :—

"Notez.—J'ay descrit un chapitre contenant la maniere de la fabrique & usage de la dixiesme progression aux parties des arcs avec leurs sinus, & declaré combien grande facilité en suit, comparée à la vulgaire soixantiesme progression, de 1 deg, en 60(1), & 1(1) en 60(2), &c. laquelle matiere pourroit ici sembler requerir sa place : Mais veu que les principaux exemples d'icelle se prennent des cours moyens des Planetes & autres comptes communs avec iceux, qui jusques ici ne sont point encores descrits, nous avons appliqué le susdit chapitre derriere le traicté d'icelles Planetes, à sçavoir en *l'Appendice* du cours des Planetes."

To which is appended the following note by Girard :—" Ceste promesse ne se trouve pas avoir esté effectuée."

Steichen, in his 'Mémoire sur la vie et les travaux de Simon Stevin' (Brussels, 1846), p. 52, says that Stevinus promises a chapter on the manner of constructing a table of trigonometrical lines " pour la division de la circonférence en parties décimales." This is not correct, as the quotation from 'La Disme' shows that Stevinus's idea was to divide the *degree* centesimally.

Briggs, in the 'Trigonometria Britannica' (p. 1), states that he was led to divide the degree centesimally by the authority of Vieta (" Ego verò adductus authoritate Vietæ, pag. 29. Calendarij Gregoriani, & aliorum hortatu, Gradus partior decupla ratione in partes primarias 100, & harum quamlibet in partes 10. quarum quælibet secatur eâdem ratione. Atque hæ partes calculum reddunt multò facilorem (*sic*), & non minus certum "). We have looked through 'Francisci Vietæ Fontenæensis. . . . Relatio Kalendarii vere Gregoriani. . . . 1600 " (Colophon: 'Excudebat Parisiis. . . .,' 40 *leaves*, as only the rectos are numbered, 1 to 40) without finding, either on p. 29 or elsewhere, any mention of the division of the degree. Without venturing to say that there is nothing of the kind in the book, it is not unlikely that the wrong work of Vieta's is referred to, as we have found many other seventeenth-century references inaccurate; and this is rendered more probable when it is remembered that the 'Trigonometria Britannica' was published after Briggs's death.

But granting, as is likely, that Briggs did derive the idea from Vieta, it is very probable that the latter himself obtained it from Stevinus, and perhaps adopted it without acknowledgment, as unfortunately it is to be feared that

* Stevinus encloses the exponential numbers in complete circles, for which we have throughout substituted parentheses, for convenience of printing.

† This refers to the preceding articles of the 'Disme,' where the decimal division is explained.

Vieta was bigoted enough to suppress the name of a heterodox author, such as in all likelihood Stevinus was. There can therefore be but little doubt that the original suggestion for the centesimal division of the degree is contained in the sentence quoted from 'La Disme;' but we intend to investigate the question further, and endeavour to decide it conclusively.

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ERRATA.

Page 6, line 8 from bottom, *for* Poggendoff *read* Poggendorff.
Page 15, line 25 from top, *for* multiplication *read* multiplication table.

Observations on the Application of Machinery to the Cutting of Coal in Mines. By WILLIAM FIRTH, of Birley Wood, Leeds.

[A Communication ordered by the General Committee to be printed *in extenso.*]

THE object of this paper is to submit for consideration some matters touching the history of the now more than ever absorbing subject of cutting coal in mines by mechanical means.

It is intended to avoid all technical and scientific symbols, and to convey, in the most simple manner, whatever information is at my command, and to give, from practical experience, spread over long periods, the results derived therefrom, and to show that machinery can be, and is now, applied to the purpose equally to the advantage of the masters and of the men.

I am aware that there are *now* several distinct modes of doing the work, and doing it well; but it is not in my power to give any reliable information upon the competitive status which the successful machines hold towards each other. I shall therefore have in this paper to confine myself more particularly to the *introduction* of coal-cutting machinery driven by compressed air, and the results obtained from the invention now known as "Firth's Machine," which was unquestionably the first that ever succeeded in reducing to actual practice the cutting of coal in mines.

When the severe nature of the employment of manual labour for the "hewing of coal" and the great dangers which beset that occupation are taken into thoughtful consideration, it is not surprising that much sympathy should have been always excited in favour of the coal-working class. All men who have thought upon the subject have felt a strong desire that some mechanical invention might be made to ameliorate the severe conditions of that occupation.

The statistics of the comparative longevity of the working classes show that the duration of the lives of colliers (apart from special accidents) is lamentably low; and as respects the "hewers" or "pickmen," whose work is the most exhausting, they must especially, and in a large degree, contribute to, and account for, much of that average shortness of life.

The really hard work of a colliery falls upon the "hewers;" and the effect is very often to stamp the men with the mark of their trade, and (through the constrained position of their daily toil) to alter and distort many of the more delicately formed persons; and it is due to these men as a class, that their weaknesses should be mildly judged, having regard to the scanty opportunities hitherto afforded to them for intellectual culture, and the unequal sacrifices which press so heavily upon them in the most valuable and important branch of all our industries.

In 1862 some experiments were commenced at West Ardsley, by the employment of compressed air, to devise a cutting-instrument in the form of a pick. It was to be moved on the face of the coal, striking in a line and with such force as would cut a groove deep enough to admit of its being easily taken out. In the early stages there were many and serious discouraging symptoms discovered, but on the whole we were well satisfied that they could be overcome by perseverance. We set about to improve the defects, and battle with the difficulties as they presented themselves; and after some years we were in possession of a coal-getting machine, in combination with air-power, more suitable for the performance of the work which we had undertaken than we ever anticipated.

Much surprise has been expressed at our slow progress during the ten years which have elapsed since the time when we believed that we had reached success; but when the peculiar circumstances which surround the work, and the nature of the work to be done, are taken fairly into account, the delay need not excite any astonishment. It was in many respects a new field to be broken up, and accompanied by numerous uncertainties. It has been more or less so with most of the important inventions which have gone before it; indeed the steam-engine, whose origin cannot be traced back, was known as a prime mover nearly two centuries before it was sufficiently developed to be recognized as a valuable machine.

We found, however, that we had to contend against much prejudice and resistance. Those who were the most likely to be benefited by it were either openly hostile or manifested an unfriendly disposition towards the machine; and, added to these embarrassments, we failed to obtain any general encouragement from those who exerted the greatest influence over the coal-mining interests of the country; but through the recent dearness of coal, the attention of the country has been drawn to the subject, the public mind has been powerfully impressed with the necessity for some improved means of working the mines, and coal-cutting machinery is now universally looked to as the principal source from which relief is to come.

From the altered feelings of the miners as to the number of hours which they consider to be sufficient for their labour, and with the new restrictions

imposed by the Legislature, there is found already at every colliery in the country a deficiency of hands to fully man the works now existing; and coal has in consequence been scarce and exorbitantly dear. The consumption goes on increasing; the continual enlargement of the old iron works, and the establishment of new ones in new districts, indicate a progressive enlargement in the demand for coal, unless a general collapse in our foreign commerce should, through high prices of production, come upon the country.

New coal-fields, too, are sought after ; and new pits are being opened in every direction, at enormously increased cost; and the question naturally arises, where are the colliers to come from to work them, or how is the increased demand to be reasonably met?

Labourers from the agricultural districts, and other unskilled workmen, may, through the influence of high wages, be drawn off to the mines; but it is only in "dead work" where they can be immediately made use of, and only a small proportion make efficient "pickmen."

By the figures laid before Mr. Ayrton's Committee of the House of Commons (1873), it appears that whilst in 1871 the average production of coal per man was 313 tons, it had declined to 296 tons per man in 1872. There had been an increase in the number of persons employed at and about the mines of 42,184. The disturbance which has been felt in nearly every other occupation seems to me to be traceable to the heavy drafts which have been made upon them to supply the increased demand for the coal and iron trades during the last two years; and until stagnation and distress in those trades shall throw back the suffering masses again upon their former employment, that disturbance must continue, with all its inconveniences.

A continuance of the present high price of coal may, and I think will, make itself felt upon the foreign commerce of this country. I believe, however, that a decided modification of these evils may be found in the speedy adoption of coal-cutting machinery.

Other countries are now turning their attention vigorously to the employment of coal-getting machinery; and it is not improbable that foreigners will in this matter take the lead in the employment of an invention purely English.

In the earlier stages of machine-working, it was contended that the "creep" of the floors, and the natural disturbances of the strata, would so dislocate or break the joints of the air-pipes, that continuous working could not be carried on, the out-put would be intermittent and uncertain, and the cost of compressing the air would be enormous and overwhelming to the enterprise.

The coal-owners during many years had had an unprofitable trade, and they were unwilling to encounter a considerable outlay of new capital in the work incident to the new system, which, indeed, had not then met with the approbation of the engineers and mining agents, whilst the mining inspectors, with very few exceptions, were decidedly mistrustful of the success of the invention. There were others who believed that the heavy work which they saw done would knock the machines to pieces, and that they could not stand the test of long-continued service.

Five or six years, however, of regular and daily working of the machines at Ardsley and elsewhere have effectually negatived these fears.

In the collier class there is a good deal of professional pride or *esprit de corps*, especially amongst the older men. There was, and still is, an unwillingness to give up the social dignity which they consider belongs to the expert wielder of the time-honoured pick; and some of them have been heard to declare that they "would adhere to the ancient implement to the end of

their days," and that they would not come down to the humiliating condition, as they considered it, of "following the machine."

This feeling on the part of the colliers has hindered the progress of machine-work more than any other difficulty; and although it yet prevails to some extent, the more intelligent and the younger men evince a contrary disposition towards it.

The leaders of the miners of Yorkshire and other districts have seen the machines at work, and, whilst they express without hesitation their unqualified approbation of them*, state frankly that *their* object will be to gain as full and fair a share of the advantage of the machines as possible for their own class. Now nobody will object to that claim; and when we come to consider the figures of cost, as we presently shall do, it will be seen that that claim has not been neglected.

Intelligence is what is required to manage these machines, rather than muscular development; and any youth of ordinary capacity can in a few days acquire sufficient knowledge to do so.

In 1761, Michael Menzies, of Newcastle, obtained a patent for cutting coal in mines; and that is the earliest evidence which we have of any attempt having been made to produce a mechanical coal-cutter; and his plans, having regard to the *time* at which they were produced, were remarkable for their ingenuity.

Menzies's specification is also remarkable in other respects, as showing that it was his intention to make use of the "Fire Engine" as his motor, which engine had about two years previously, through the improvements of Watt and of Smeaton, attained only to so much perfection as to become a doubtful rival to the "Water Miln," the "Wind Miln," and the "Horse Gin."

By the power of one or other of these agents, he proposed to give motion to a heavy iron pick, made to reciprocate by means of spears and chains, carried down the pit, and with wheels and horizontal spears, on rollers, extended to the working places, and there to "shear" the coal exactly as it is now performed. In the same patent Menzies included a "Saw" to cut the coal; and although nothing came from his labours, he displayed so much mechanical knowledge as to have deserved success; and I am satisfied that his failure was due to the absence of an eligible power, and not to his deficiencies as a mechanic.

During the hundred years that followed these events, more than a hundred other patents were applied for and granted; but I cannot find, amongst them all, that there was one machine that approached nearer to success than the invention of Michael Menzies.

This fact is not referred to in disparagement of the patentees; for there were many curious devices, ingeniously arranged; but I name the matter to show

* Extract from Letter received by the West Ardsley Company, dated 22nd February, 1872, from Mr. Philip Casey, of Barnsley, Secretary to the South Yorkshire Miners' Union.

"Will you allow me to express the gratitude which I feel for the pleasure I derived in visiting your works yesterday?

"For many years the name of Mr. Firth has been known to me in connexion with his efforts to lighten the heavy labour incidental to mining operations; and the coal-bearing machine that I saw in operation at the West Ardsley Works altogether exceeded my expectations.

"I cannot see how the coal could possibly pay to be got by hand; its extreme hardness, coupled with the thinness of the seam, would make it utterly impossible. This machine is the best friend the collier ever had; but it will be our business to obtain a full and fair share of its benefits to our people."

that the object excited much continuous interest, and that amongst so many miscarriages our mechanics were still hopeful.

Amongst these devices may be enumerated the "Saw," "Catapult," "Battering-Ram," "Plough," "Rotary Wheel," "Endless Chain," "Planing Machine," and many others.

There had been no suitable power made known for driving the machines; and it was to that cause, in my opinion, that so many failures and disappointments were attributable. The steam engine, even since it attained to its most perfect form, is in itself insufficient for the purpose, because steam cannot be produced near to the place where the work has to be done, nor can it be carried long distances in effective condition, by reason of its rapid condensation. Moreover an escape of exhaust-steam could not be permitted in the coal-mine, because of its tendency to soften and bring down the roof, the difficulty of maintaining which is already the most serious and troublesome part of the coal-mining operations.

Hydraulic power might in certain cases be, and has been recently tried; but its unfavourable conditions exceed its advantages for the purpose of cutting coal in mines, and may be put aside from present consideration.

But in compressed air, so far as the moving power is concerned, every requirement is found, and from the date of the experiments at West Ardsley, in 1862, the question was undoubtedly settled.

The elastic property of air under compression is an old and well-known power; but until these experiments had been completed, its value was but imperfectly understood, and its future beneficial influence, being dormant, was unappreciated.

The engine for compressing the air is generally placed on the surface, near to the top of the shaft; a receiver is fixed in close proximity thereto; and the air is taken from the compressor to the receiver, which is 30 feet in length and 4 feet in diameter.

The pressure is generally of about three atmospheres.

Iron pipes of sufficient area are laid on from the receiver to the bottom of the shaft, and there, being split into smaller sizes, are led in every needed direction through the roads and passages of the mine, exactly as the gas and water services are laid on in our towns.

At the entrance into the working places, a screw joint and stopcock are fixed to the iron air-pipe, at which point an india-rubber hose, fifty or sixty yards in length (as the length of the "benk" may require), is screwed on; the other end of the hose is attached to the cutting machine; and when all is in readiness, the tap at the receiver is turned on, and the air rushes down, and throughout the whole service of pipes.

The air does not require to be forced from the receiver, for by its own elasticity it is carried forward at a velocity depending on its own pressure.

Apparently it loses none of its power by distance, excepting the frictional retardation; and machines are working nearly two miles distant from the air-engine without any material loss of force.

I have no doubt that if the compressor were stationed in Bradford the air would travel, and the machines work by it at Ardsley (ten miles) as satisfactorily as they now do by the engines on the spot.

In calculating the cost of compressed air, I am satisfied that, although it is admittedly not a cheap power relatively to steam, yet there is no other available power so cheap or so good for the purpose of cutting coal in mines; and I invite attention to the figures on this head which follow, viz.:—

With well-constructed machinery, 45 to 50 per cent. of the steam power

exerted will be given off in compressed air at a pressure of three atmospheres into the receiver; and this pressure is sufficient for effectually working our machinery. Some makers of air-engines offer to guarantee a much larger product; but I base my calculations upon the smaller yield.

If the pressure be much higher than three atmospheres, there is a material increase in the frictional heat disengaged by the act of compression. The engines do not work with the same ease; and the result of our experience is, that at 45 to 50 lbs. the maximum point of economy is attained. Calculating its cost and taking a 40-horse-power boiler to consume 10 lbs. of coal per hour per horse-power, or 2 tons of engine-coal per day of 11 hours at 8*s*. per ton at the pit, we have a cost of 16*s*. per day.

It is safe to calculate that this boiler will drive an engine of sufficient power to supply four coal-cutting machines, being 4*s*. per day for each machine; and each machine will cut more coal in any given time, and do it in a better manner, in an ordinary seam, than twelve men; it follows, therefore, that the equivalent of a man's power exerted for a whole day in cutting coal, can be obtained, out of compressed air, at a cost in fuel of but $3\frac{1}{4}d$.

Assuming, then, that this comparison is an accurate one, it may be taken for granted that the objection to its use, on the score of cost, has no foundation in fact.

And considering its many and remarkable properties for employment in coal-mines, it may be useful to dwell briefly on some of those peculiarities.

It is a power from which, and under no circumstances, can an explosion happen; and when an escape from the pipes takes place, it is more or less *beneficial*, and not in any wise injurious.

At every stroke of the piston the air is discharged from the cylinder of the coal-cutting machine at a temperature of about freezing-point, compressed into one third of its natural bulk; and it has been found that the working of only one machine has had the effect of reducing the temperature at the working face of the coal to the extent of two degrees Fahrenheit.

Occasionally ice is formed at the escape valves of the machine, but without producing any inconvenience to their working.

Now any thing that will reduce the temperature of a mine is an inestimable advantage. It diminishes the risk of explosion; and by increasing the velocity of the ventilating current, it renders the occupation of a miner more tolerable and more healthy.

In *very deep* mines the internal heat will probably be found to be so great, that manual labour of an exhausting character will be unendurable; but the discharge of so large a volume of pure air at a pressure of three atmospheres, and at freezing-point, must exert a powerful and highly favourable influence under the peculiar circumstances.

It is well known that the lives which are lost through *explosions* of gas are far more numerous from *the effect of the damp which follows the fire*, than from the *fire itself*; and in many cases nearly, if not all, the sufferers have died from this cause.

There has been no case of fatal explosion within the experience of our machine workings; and therefore we have no facts upon which absolute reliance can be placed; but we draw the inference, that where coal-cutting machinery may be in general use in any mine where an explosion of gas does take place, those who escape from the first effect of the fire will most probably be saved from death.

At a lamentable accident in this neighbourhood about two years ago, when thirty-one lives were lost, twenty-five or twenty-seven of those unfor-

tunate persons died from the effect of the "afterdamp;" two of the men were fortunately saved by a very small current of air which was turned upon them by a brattice cloth, and which supported life until they were released*.

If the compressed air-pipes had been in those workings at that time, it is not unreasonable to believe that very few, if any, of those twenty-five men would have succumbed.

There is another useful purpose incidental to the use of coal-cutting machinery in mines, which it is worth while to notice; and that is in the event of a *pit being on fire.*

At West Ardsley a "blown-out shot" ignited the gas and set fire to the goaf. It extended to the face of the coal, and had taken strong hold of it, and the whole pit was in the greatest danger. There is a large water-tank at the surface for supplying the boilers and coke-ovens; and the manager promptly connected the air-pipes to the water-tank and turned the water into the fire.

In less than an hour the fire was completely extinguished without any serious damage. On a previous occasion the same colliery was on fire, and had to be closed up. That fire cost us many thousands of pounds. It happened before the introduction of the coal-cutting machinery.

Compressed air is also becoming extensively used for "hauling," and with very great advantage. Small engines can be set up wherever convenience or necessity may require; they are portable and removable at a trifling expense, and are available where no other mechanical power for traction can be obtained.

It is also valuable for pumping water, and "drilling" the holes where the coal has to be "blasted," or broken down by the hydraulic press.

Enough has been said respecting this remarkable and diversified power to justify the expectation that it is the key to vast and important improvements upon the present system of working coal; and bearing in mind that the wealth, the power, and the greatness of this nation depend primarily upon an abundant supply of coal, it is hardly possible to overrate the importance or overvalue the advantage which this power places at our disposal.

I now turn to the consideration of the machine for cutting the coal, which has for several years been employed at West Ardsley without any interruption. [A model and photograph were exhibited to show its form and construction.] The weight is about 15 cwt. for a machine of ordinary size, its length 4 feet, its height 2 feet 2 inches, and the gauge 1 foot 6 inches to 2 feet; it is very portable and easily transferred from one benk to another.

The front and hind wheels of the machine are coupled together in a similar manner to the coupled locomotive engines. The "pick," or cutter, is double-headed, whereby the penetrating power is considerably increased.

The groove is now cut to a depth of 3 feet to 3 feet 6 inches at one course, whereas by the old form of a single blade we had to pass the machine twice over the face of the coal to accomplish the same depth. The points are loose and cottered into the boss; so that when one is blunted or broken, it can be replaced in a few moments. This dispenses with the necessity of sending the heavy tools out of the pit to be sharpened, and is an immense improvement upon the old pick.

When all is in readiness for work, the air is admitted and the reciprocating

* I am informed that at the accident at the Oaks Colliery, near Barnsley, in 1866, forty-five persons were found dead in one place, and seventy in another, who were lost for want of a little air; and it is believed that many more at that time died from the same cause.

action commences. It works at a speed of sixty to ninety strokes per minute, varying according to the pressure of the condensed air, the hardness of the strata to be cut, or the expertness of the attendant.

As to the *quantity of work* in "long wall," a machine can, under favourable circumstances, cut 20 yards in an hour to a depth of 3 feet; but we consider 10 yards per hour very good work, or say 60 yards in a shift.

This is about equal to the day's work of twelve average men; and the persons employed to work the machine are one man, one youth, and one boy, who remove and lay down the road and clear away the débris.

The machines are built so strong that they rarely get out of working condition. Some of those now working at West Ardsley (and other places) have been in constant use for three or four years.

At that colliery there are about eight machines in use. One of the seams is so hard and difficult to manage that it could not be done "by hand," and the proprietors had to abandon, and did abandon it; but *now*, by the employment of the machines, it is worked with perfect ease.

It is a thin cannel seam with layers of ironstone; and the machines now "hole" for about 1200 tons per week.

The groove made by the machine is only 2 to 3 inches wide at the face, and $1\frac{1}{2}$ inch at the back; whereas by hand it is 12 to 18 inches on the face, and 2 to 3 inches at the back.

Thus, in thick seams worked by hand, the holing is often done to a depth of 4 feet 6 inches to 5 feet, and the getter is quite within the hole that he has made; and where the coal does not stick well up to the roof, or where there is a natural parting, there is great difficulty and danger from "falls of coal."

Referring to a section, it was observed that the angle of the cut is such that, when the upper portion falls off, there is nothing for it but to pitch forward into the road; but by machine "holing" with a perfectly horizontal groove, when the coal falls it simply settles upon its own bed, and has no tendency to fall forward.

The cost of applying coal-cutting machinery is an important part of the question; but it frequently happens that at old-established collieries there may be surplus power, which can be utilized; but supposing that every thing has to be provided new, then the following may be taken as an approximate estimate of the necessary outlay:—

2 Boilers at £500 each	£1000	say £5000
1 Steam-engine	1250	
10 Machines at £150 each	1500	
Pipes, receiver, fixing and sundry other outgoings	1250	

This outlay would provide all necessary power and plant for the regular working of eight machines, with two in reserve; and estimating that each machine will cut 60 yards per day, the product in a 4-feet seam would be 85 tons per day, or per week say 500 tons per machine; and 8 by 500 is 4000 tons.

Now at this rate of expenditure and work done, an allowance of 2*d.* per ton would in three years liquidate the entire outlay.

But there is no reason why the machines should be restricted to a single shift daily; indeed it is far more economical to work double shifts: there is no additional outlay of capital; and so far as depends upon the machinery, the output might be easily increased to 8000 tons per week.

We now come to the relative costs of cutting the coal by *hand* and by

machine; and the following figures may be taken as representing a somewhat favourable state of things for the latter.

The seam is the "Middleton Main" or "Silkstone bed." The depth of the mine is 160 yards, and the coal 4 feet thick; there are two bands of shale, with a thin layer of coal between them.

The bottom portion is not always wholly merchantable; but when it is so, it yields one ton and a third of a ton per running yard. For the purpose, however, of this comparison, I take 60 tons only per day (which would come out of 45 yards of machine working).

All cut on the end.

THE COST BY HAND.

	£	s.	d.	£	s.	d.
30 men cutting, filling, timbering, drilling, road-laying, blasting, and all other needful work ready in the corves for the "hurrier" at 4*s.* $5\frac{3}{4}$*d.* per ton				13	8	9

BY MACHINE.

	£	s.	d.	£	s.	d.
1 machine man at 8*s.* 6*d.*	0	8	6			
1 youth at 5*s.* 6*d.* (equal to 1 man)	0	5	6			
1 boy at 3*s.* 6*d.* (equal to 1 man)	0	3	6			
3 men cleaning and packing at 8*s.* 4*d.*	1	5	0			
6 men filling 10 tons each man, at $8\frac{1}{4}$*d.* per ton	2	1	3			
3 men timbering at 6*s.* 10*d.*	1	0	6			
3 men drilling and blowing down at 6*s.* 10*d.*	1	0	6			
$\frac{1}{8}$ portion of cost of steam and air expenses	1	14	0			
Maintenance at 1*d.* per ton	0	5	0			
Redemption of capital at 2*d.* per ton	0	10	0			
				8	13	9
Difference, in money, in favour of the machine, or 1*s.* 7*d.* per ton				4	15	0
				£13	8	9

The two boys, it will be noticed, are taken as equal to one man; and for the purpose of another comparison, I will assume that by hand labour thirty men will produce 60 tons per day, or two tons each, and that by machine seventeen men will produce the same tonnage. The saving in number, therefore, would be twelve men to every 60 tons, or upon a colliery getting 4000 tons per week, the saving would be 132 men.

I do not wish to press this point further than to say that the cost of dwellings properly to domicile *one half* of this number would exceed the first outlay of capital in furnishing a first-class colliery with first-class machinery for cutting the coal; and it must not be forgotten that the equipment of the *hand-cutters* in tools forms a considerable item in the first cost of fitting up a colliery.

It has been generally supposed that our machines are not adapted for "pillar and stall work."

That their locomotion "is not so easy as that of men," must of course be

admitted; but they are removed from place to place with little more trouble than a full corve; and we have recently made some careful experiments, which prove that there is in "pillar and stall" about equal advantage as in "long wall;" and we can confidently assert that the opinions upon the difficulty of moving them which have been recently enunciated from high quarters are quite erroneous.

The items of cost in working contained in the previous account, are confined to the actual working of the two systems, up to the coal being put into the corves, and ready for being sent out of the pit, all the other work, whether for hand or machine, being exactly alike.

But there are some advantages in the machine over the hand-working, which pertain to the general mine account, viz. the larger size of the coal brought out, and an increased average price, on sale, with a saving in timber and other stores.

I may say in conclusion, that, putting aside entirely all reduction in the cost of getting out the coal, there are other and collateral considerations which are, in my opinion, sufficiently important and worthy of your attention.

I now recapitulate the most prominent points upon which I rely, viz.:—

1. Greater safety for the workmen from falls of coal and roof.
2. Less danger of explosion, and greater security against the effect of choke damp.
3. Less strain upon the physical powers of the labourers, and great amelioration in the hard conditions of their employment, consequently adding to the comfort and length of their lives.
4. Saving from destruction much of the most valuable of all our commodities.
5. Saving of timber and other materials employed in mining.
6. Increased control over production, enabling sudden demands to be suddenly met.
7. Preparing for other important improvements in mining, without any addition to the first outlay, such as drilling, hauling, and pumping.
8. The peculiar adaptability of the means set forth for working the very deep seams of coal, without which it is very doubtful whether they can ever be profitably worked.
9. Greater saving of time in opening new pits, and quickening the means of such becoming remunerative.

Considering the vast extent of the trade in coal and the stupendous consequences of a short and insufficient supply, and believing that the speediest adoption of coal-getting machinery is desirable, I have myself made some efforts to stimulate that object by an offer of a premium of £500 for the best machine that could be produced; but those efforts have failed, and I now submit that the question, being of national importance, is one specially entitled to the support and encouragement of the Government, and that the British Association is preeminently the channel through which that object could be obtained in the best manner.

Concluding Report on the Maltese Fossil Elephants. *By* A. Leith Adams, *M.B., F.R.S., F.G.S.*

It is with much pleasure I have to announce to the members of the Association that my labours in connexion with the fossil elephants of Malta have been completed.

It is now thirteen years since these researches were begun; and although frequently interrupted by other engagements, the importance of the subject has all along stimulated me to make every sacrifice within my power in order to accomplish a work of so much scientific interest. The monograph descriptive of the elephantine remains discovered by me was read at the concluding meeting of the Zoological Society of London in June last, and will appear in due course in the Transactions of the Society.

It is illustrated by a map and 21 Quarto plates. In my Second Report in 1866, drawn up immediately after the termination of my explorations, I was disposed towards an opinion that the exuviæ I had brought together represented only one form of Elephant, distinct from any known member of the genus, and somewhat under the ordinary dimensions of the living species. Subsequent examinations, however, showed, in addition, that there were good indications of the presence of the two dwarf elephants previously determined by Dr. Falconer and Mr. Busk, from the collection made by Capt. Spratt in the Zebbug Cave in Malta in the year 1859.

1st. With reference to the largest species. This is represented in my collections by nearly the entire dentition and many bones of an elephant which varied in height between 6½ and 7 feet. The last figure, however, represents the maximum proportions as far as I have been enabled to determine from my own specimens and from all other remains hitherto discovered in the island. It is apparent, therefore, that the largest Maltese fossil elephant was, comparatively speaking, a small animal. The dental specimens I have assigned to this species are very numerous, and for the most part perfect. They represent every stage of growth, from the first to the last, showing what appears to me an unbroken series of molars which display the progressive succession of ridges characteristic of the subgenus *Loxodon*, and are therefore allied to the existing African elephant, from which, however, they differ not only in relative dimensions, but also in well-marked specific characters.

The ridge-formulæ of the deciduous and true molars of this species seem to me to stand thus *:—

Milk-Molars.	True Molars.
x 3 x : x 6 x : x 8–9 x : :	x 8–9 x : x 10 x : x 12–13 x.

From these figures it will be apparent that the nearest alliance as regards the ridge-formula would be to the gigantic *Loxodon meridionalis*, whilst the crown sculpturing of the molars resemble the same in *Elephas antiquus*; but they do not agree in further particulars with other species excepting the *Elephas melitensis*, to which I will refer presently. With reference to the skeleton generally, the majority of the characters of the long bones are more in keeping with the African than the Asiatic elephant.

The presence of this larger species of elephant, in conjunction with the dwarf forms, was pointed out by Dr. Falconer, and subsequently by Mr. Busk; but their specimens were much too fragmentary to allow of specific determination, a want, however, which is amply supplied by the materials collected by me.

* x stands for talons.

In the choice of a name for this proboscidian I have been prompted by considerations purely incidental, inasmuch as the gap or rock-fissure from which I obtained the most perfect specimens of its teeth and bones is situated in the immediate vicinity of a remarkable megalithic structure supposed to have been built during the Phœnician occupation of the Maltese Islands. I have accordingly named this new species the *Elephas mnaidriensis*.

2nd. The dwarf species named *Elephas melitensis* by Falconer and Busk is well shown in my collection by many important bones, besides what appears to me to be the entire dental series. This species seems to have varied considerably in size; indeed it would appear to link the two extremes represented by the *Elephas mnaidriensis* and the smallest form, *Elephas Falconeri*. The majority of the bones indicate, however, that its average height may have been nearly 5 feet, as previously estimated by Dr. Falconer and Mr. Busk, from the Zebbug collection. The dentition of *Elephas melitensis*, as determined by Falconer, receives ample confirmation from the data furnished by my collections, the ridge formula being:—

Milk Molars.	True Molars.
x 3 x : x 5 x : x 8 x.	x 8–9 x : x 9–10 x : x 12 x.

The only discrepancy between our estimates is an additional ridge in the penultimate true molar of my specimens, which it may be observed is not a rare occurrence in the equivalent tooth of the African elephant. It is clear therefore that, like the larger form, the above belonged to the Loxodon group, with a ridge-formula almost identical to that of *E. mnaidriensis*, excepting in the penultimate milk-molar, which in the former holds 5 instead of 6 plates, besides talons—a distinction maintained in various specimens in my collection.

The crown-patterns of worn molars in the two elephants are also very much alike; but the relative dimensions of teeth of equivalent stages of growth differ a great deal, indeed more so than perhaps in large and small individuals of any known species.

Again, we find thick- and thin-plated varieties among the last true molars of both forms, just as obtains in other species; so that, taken in conjunction with the bones, it seems to me that they cannot be reconciled with sexual or individual peculiarities of one species of elephant.

3rd. The smallest adult bones in my collection represent a very diminutive elephant. In some instances, as compared with other species, there are evidences of individuals even under 3 feet in height. With reference to dental materials, there is some variety in dimensions of molars ascribable to the *Elephas melitensis*; but, allowing a fair margin in this respect, and taking into consideration their absolute similarity in every other particular, it seems to me impossible to make out a third species from the teeth alone. There are, however, vertebræ and other bones which fairly establish the pigmy proportions of the *Elephas Falconeri* of Busk; at the same time there is no difficulty in arranging a graduated series of specimens, from the smallest up to the largest bones ascribable to the *Elephas melitensis*.

But whilst the differences in size between the two dwarf forms are not so great as usually obtains between large and small individuals of living species, there is a remarkable dissimilarity in this respect between the largest specimens representing the *Elephas mnaidriensis* and the smallest of *Elephas Falconeri*; indeed the estimated height of the former shows an elephant nearly three times as tall as the latter, thus displaying a range much exceeding any known instances of individual variation among recent and extinct species.

I am thus particular to record these facts in order to show what appears to me evidence that the dwarf forms were not females or small individuals of *Elephas mnaidriensis,* although the latter was, comparatively speaking, a small species, and agreed, at all events, with *Elephas melitensis* in many important particulars. Unless, therefore, a far greater variability of species existed in those times than at present, after making every allowance for size and other characters, I see no avoiding the inference the materials force on us, viz. that there lived in the Maltese area two, if not three, distinct species of elephants different from any known forms. It is necessary to say a few words with reference to their associated fossil fauna. In the first place, all the elephantine forms have been found in the same deposits, and usually intermingled. Along with them we find bones and teeth referable to the *Hippopotamus Pentlandi* and *H. minutus.* The former has been met with in great abundance in the island, whilst only a few teeth and other portions of the skeleton of the latter have turned up. Here again we observe a great variability in dimensions; indeed in this respect these two riverhorses resemble the large and pigmy forms of the elephants; and although the former have been found in a fossil state in Sicily and Crete in conjunction with other mammals, this is not the case with the giant dormice and large extinct swan, which have hitherto turned up nowhere out of Malta. I may state that the Reptilian remains found by Admiral Spratt and myself in union with these quadrupeds and birds have not, as a whole, been critically examined; but, in consideration of the importance of the subject, I am in hopes of seeing this accomplished soon.

The mollusca found in connexion with foregoing represent several recent species, which have been already noticed in my first Report for 1865.

It must be apparent, therefore, that this (for the most part) unique fossil fauna, restricted to a small mid-ocean island, presents several interesting contrasts with reference to the Mammalia in general, and elephants in particular, which frequented Europe during late geological epochs. For example, between Rome and Sicily we find remains of the *Elephas primigenius, Elephas antiquus,* and *Elephas meridionalis.* In the caves of Sicily traces of the African elephant have been discovered, and also molars, barely distinguishable from those of the Asiatic species, and which, under the name of *Elephas armeniacus,* are traceable eastward into Asia Minor, in the direction of the present habitat of the living species. It looks, indeed, as if the eastern basin of the Mediterranean had been at one time a common ground where all these extinct and living elephants met, and whence, with other animals, they have disappeared or been repelled to distant regions.

In fine the importance of late discoveries in this area, and the circumstance that the explorations have been hitherto restricted to isolated points along the shores and islands of the great inland sea, promise well for future researches; indeed I might be permitted to say that if one quarter of the superfluous zeal and energy of the rising generation of English geologists were directed towards the ossiferous deposits of Southern Europe and Northern Africa, we should not have long to wait for novelties equally interesting with any yet produced.

In conclusion, I beg once more to express my deep obligations to the British Association for the valued assistance extended to me not only during the prosecution of the explorations, but also with reference to the illustration of the various and interesting materials I have described at length in my memoir, of which this is but a brief abstract.

Report of the Committee, consisting of Professor RAMSAY, Professor GEIKIE, Professor J. YOUNG, Professor NICOL, Dr. BRYCE, Dr. ARTHUR MITCHELL, Professor HULL, Sir R. GRIFFITH, *Bart.*, Dr. KING, Professor HARKNESS, Mr. PRESTWICH, Mr. HUGHES, Rev. H. W. CROSSKEY, Mr. W. JOLLY, Mr. D. MILNE-HOLME, *and* Mr. PENGELLY, *appointed for the purpose of ascertaining the existence in different parts of the United Kingdom of any Erratic Blocks or Boulders, of indicating on Maps their position and height above the sea, as also of ascertaining the nature of the rocks composing these blocks, their size, shape, and other particulars of interest, and of endeavouring to prevent the destruction of such blocks as in the opinion of the Committee are worthy of being preserved. Drawn up by the* Rev. H. W. CROSSKEY, *Secretary.*

THE Royal Society of Edinburgh has appointed a Committee for the special examination and description of Boulder or Erratic Blocks in Scotland; and it will therefore not be necessary for this Committee to include Scotland in its investigations.

Throughout England and Wales boulders and groups of boulders are scattered, among which the work of destruction is constantly going on. Groups of boulders are removed from the fields and built into walls; large boulders are frequently blasted; and during these operations the signs of ice-action are either rendered obscure or entirely removed.

The geological importance, however, of obtaining the exact facts respecting the distribution of travelled boulders is increasing with an extended knowledge of the very complicated character of the phenomena of the glacial epoch. The dispersion of boulders cannot be traced to *one single period* of that great epoch.

Prof. Ramsay has pointed out that transported blocks have travelled in some instances over land higher than the parent beds from which they have been derived, thus affording support to the theory that oscillations of the land took place during the one great glacial period, which would necessarily be accompanied by a series of dispersions of boulders*.

The distances of the boulders from the rocks from which they were derived, the heights over which they have passed and at which they are found, the matrix (if any) in which they are imbedded, whether of loose sand, gravel, or clay, will form elements in determining at what period in the glacial epoch their distribution took place.

As the dispersion of boulders cannot be traced to one single period, neither can it be referred to *one single cause*.

The agency of land-ice, the direction in which icebergs would float during the depression of the land, the power of rivers in flood to bring down masses of floating ice, must be taken into account.

It will not be the office of this Committee to offer theoretical explanations, but to collect facts, although the bearing of these facts upon debatable geological problems may from time to time be not unjustly indicated.

While the dispersion of boulders can neither be traced to one single period nor referred to one single cause, in some cases boulders distributed at different periods and by different causes may have become intermixed. This possibility, of course, largely adds to the complexity of the problems involved, and to the difficulty of assigning to various isolated boulders and groups of boulders their definite place in a great series of phenomena.

The following circular has been distributed by the Boulder Committee of the Royal Society of Edinburgh:—

* Quart. Journ. Geol. Soc. vol. xxix. p. 360.

' *If there are in your Parish any* ERRATIC BLOCKS *or* BOULDERS,— i. e. *Masses of Rock evidently transported from some remote locality, and of a remarkable size, say containing above* 10 *cubic yards*—i. e. *about* 20 *tons,—please to answer the following Queries* :—'

QUERIES.	ANSWERS.
1. What is name of the Parish, Estate, and Farm on which Boulder is situated, adding name of Proprietor of Estate, and Tenant of Farm?	
2. What are dimensions of Boulder, in length, breadth, and height, above ground?	
3. Is the Boulder, in shape, rounded or angular?	
4. If the Boulder is long-shaped, what is direction by compass of its longest axis?	
5. If there are any natural ruts, groovings, or striations on Boulder, state— (1) Their length, depth, and number (2) Their direction by compass ...... (3) The part of Boulder striated, viz. whether top or sides	
6. If the Boulder is of a species of rock differing from any rocks adjoining it, state locality where rock of the same nature as the Boulder occurs, the distance of that locality, and its bearings by compass from the Boulder?	
7. What is the nature of the rock composing Boulder, giving its proper Geological or Mineralogical name, or other description?	
8. If Boulder is known by any popular name, or has any legend connected with it, mention it.	
9. What is the height of Boulder above the sea?	
10. If Boulder is indicated on any map, state what map.	
11. If Boulder is now, or has been, used to mark the boundary of a County, Parish, or Estate, explain what boundary.	
12. If there is any photograph or sketch of the Boulder, please to say how Committee can obtain it.	
13. Though there may be no one Boulder in your Parish so remarkable as to deserve description, there may be groups of Boulders oddly assorted; if so, state where they are situated, and how grouped. Sometimes they form lines more or less continuous,—sometimes piled up on one another.	
14. If there are in your Parish any "Kames," or long ridges of gravel or sand, state their length, height, and situation.	

It is proposed by the Committee to issue a similar circular, with some modifications, to Secretaries of Field-clubs and local Geological Societies in England and Wales, and others who may be willing to assist in their work.

The Committee would especially invite the cooperation of the various field-clubs of England and Wales, whose members, in their various excursions, enjoy singular opportunities of becoming acquainted with the boulders of the country.

Charnwood-Forest Boulders.

The railway-cutting at Hugglescote, approaching Bardon Hill, passes through an immense number of striated and polished boulders. Mr. Plant, of Leicester (who has investigated the boulders of this district, and furnished us with considerable information), describes this cutting at Hugglescote as 30 feet deep. The drift-gravel is a hard cemented mass, with hundreds of erratics, at all heights, sticking not on their longer faces, but sometimes on end, distinctly proving that the ice melted *in situ*, and left the materials to find their own bearings. One, of which he saw the fragments, had to be blasted to get it out, and was estimated by the engineer to weigh 10 tons.

All the boulders (except one, a peculiar millstone-grit) were derived from the Charnwood-Forest range, the most travelled from a distance of 30 miles, the nearest about 2 miles.

Some of the boulders were upwards of 5 tons in weight, and were striated and polished frequently on more than one side. Many were angular and subangular. They were very irregularly dispersed through an unstratified matrix of sand and clay.

The whole distance from the vast accumulation in the cutting to Bardon Hill, the nearest point of Charnwood, a distance of about 2 miles, is covered with trails of boulders.

The jagged edges of the Bardon-Hill rock, 854 feet above the sea-level, indicate the way in which boulders would be broken off, supposing the hill itself covered with ice.

During some part of the glacial epoch Charnwood Forest was evidently a centre from which highly glaciated boulders were distributed.

Mr. Plant reports that a great south front of igneous rock has been broken down and distributed, east, south, and south-west, 10, 15, and 20 miles, in direct lines.

An area of 10 miles N.N.W. and 20 miles S.S.E. and S.W., is covered with boulders derived from Charnwood Forest, from 2 cwt. up to 10 tons.

Centuries of cultivation (he adds) have been occupied more or less in clearing the surface of these boulders. They are still found in great numbers, 2 to 3 feet deep; but the surface-boulders are found in the walls of village houses, churches, farm-houses, and other old structures, all over the county.

Four large blocks from the railway-cutting at Hugglescote have been removed, and placed in the grounds of the Leicester Museum. One of these is a fine example of a polished rock, and is full of ice-grooves. Its dimensions are:—6 ft. high, 3 ft. 2 in. broad (or thick), 3 ft. wide; weight nearly 4 tons. It consists of "porphyritic greenstone" from Charnwood Forest, grey felspathic base (dolerite), with crystals ($\frac{1}{4}$ to $\frac{3}{8}$ on face) of quartz. Through long chemical action in the drift the felspar has been decomposed, and left the crystals standing out all over the surface, except on the polished side. The other three blocks are nearly of the same size and composition.

It is intended to remove other blocks to the museum-grounds for preservation.

Charnwood Forest and other Boulders, beneath marine sands and gravels, 357 feet above the sea.

At the base of Ketley gravel-pit, near Wellington (Shropshire), is a bed of very fine sand, containing a remarkable group of large angular and subangular boulders.

The sands and gravels extend to heights of from 25 to 30 feet, and yielded 13 species of mollusca, chiefly in fragments.

Cardium edule, *Linn.*	Dentalium —— ? (very worn).
—— echinatum, *Linn.*	Turritella terebra, *Linn.*
Cyprina islandica, *Linn.*	Natica grœnlandica, *Beck.*
Astarte borealis, *Chemnitz.*	Buccinum undatum, *Linn.*
—— sulcata, *Da Costa.*	Trophon truncatus, *Strom.*
Tellina balthica, *Linn.*	Nassa reticulata, *Linn.*
Mactra solida, *Linn.*	

It will be observed that only one of these species is extinct in British waters, viz. *Astarte borealis.*

Throughout the sands and gravels waterworn pebbles are found, with occasional masses of larger size, composed of the same material as the larger boulders beneath.

Beneath the marine sands and gravels some of the boulders are 8 feet by 5 feet, and their sides are planed very smoothly, and they have a subangular shape.

Out of 100 specimens, 80 per cent. consist of Permian sandstones from the immediate neighbourhood.

From the immediate neighbourhood also there are boulders of

Mountain Limestone.	Silurian Limestone.
Old Red Sandstone.	Greenstone.

The travelled boulders consist of

Various granites, both red and grey (very numerous), probably from Cumberland or Scotland.

Rocks of Charnwood Forest, from a distance of 50 miles.

One remarkable feature of this group of boulders is the intermixture of boulders from the neighbourhood *with those that have travelled from different points of the compass*, the whole group being buried beneath marine sands and gravels, at the elevation of about 300 feet above the sea. The elevation of Ketley village is 357·319 feet above the sea.

For the boulders of the neighbouring drift of the Severn valleys reference may be made to an exhaustive paper by Mr. G. Maw (Quart. Journ. Geol. Soc. vol. xx. p. 130).

The Geological Section of the Birmingham Natural-History Society has commenced a systematic examination of the boulders of the Midland district, and has favoured the Committee with the following preliminary Report:—

"The Ordnance Map of the neighbourhood of Birmingham has in the first place been divided by ruled lines into squares of one inch side, each square enclosing a representation of one square mile of country. Enlarged maps, on the scale of six inches to the mile, were prepared from this; and on these enlarged maps the boulders were to be marked by circles, the number of concentric circles representing the diameter of the boulder in feet. For collecting specimens of the rocks of which the boulders are composed, bags were made, and numbered corresponding to each square on the map; at the same time notes were to be made of any specimen that was of unusual interest.

Finally, it was proposed to represent, on a duplicate map, the number of boulders and character of the rocks by disks of colour, so that a graphic representation of the boulders, as to position, numbers, and kind of rock, would be given, and the source of any class of boulders (as granite *e. g.*) could be readily traced. It was further proposed to number a rough relief-map of the district, so as to judge in what way the configuration of the country had affected the distribution of the boulders.

"Considerable information has been already obtained, of which the following is a summary:—

"A difficulty was experienced in defining the term *boulder*; and, after much discussion, it was thought that for the district the following definition would serve:—'A boulder is a mass of rock which has been transported by natural agencies from its native bed.' Respecting the size at which a rock may be called a boulder, it is thought better not to assign any very definite limit. Some specimens, measuring not more than a foot in some one direction, are both transported from great distances and glaciated, and fairly fall into the category of boulders.

"*Distribution of the Boulders.*—The district has not as yet been sufficiently examined to report fully on this question. There are unquestionably some places where great accumulations have taken place, separated by country with only a few boulders per square mile. The places where large accumulations (a thousand or so) occur, as far as has yet been ascertained, are:—

1. Tettenhall. 2. Bushbury. 3. Cannock.

Places where moderate accumulations (50 to 100 or 200 per square mile) occur:—

Penkridge.	Stone.
Shareshill.	Shifnall.
Brewood.	Harborne, near Birmingham.
Codsall.	Bridgenorth.

"The southernmost point where boulders have been observed is on the left of the lane leading from Bromsgrove Station to the town, the most eastern at Rugeley, where only two or three occur.

"It has been suggested that the cause of accumulations of boulders is due to the stranding of an iceberg at the place in question; but at present there is not sufficient evidence to form any satisfactory opinion as to the cause of the accumulation.

"The boulders of the Midland district seem originally to have been imbedded either in clay or drift-sand; but it is quite the exception to find them *in situ*. They seem commonly to be disturbed by farmers in the district, who meet with them when ploughing. If the boulder be of manageable size, it is at once dug up and turned into the nearest ditch, or sometimes is buried, or, it may be, carried to the road-side, and broken up for road-purposes. Farmers find some of the boulders useful as horse-blocks, or for protecting gate-posts or the corners of walls and buildings; and it is thus that many are preserved. If the boulder be a very large one, it is generally left in the ground, and the plough carried on each side of it. Since a plough may pass over a boulder several times before the men will take the trouble to remove the obstruction, there is every chance for the boulder to become marked by striations; and hence much care is required in forming a judgment as to the origin of striæ which may be found upon it. It should be mentioned here that boulders gradually 'work up' to the surface. This is due no doubt to

the denudation which is taking place. In a field near Red-Hill Farm, between Stafford and Stone, is one of the largest boulders of the district. This boulder was not noticed until some twenty years ago, when it was found to obstruct the plough, although still some depth underground. The obstruction became more and more serious each year, until a few years ago, when, because of this impediment, the field was turned from an arable to a grazing one. At this time the boulder rises about one foot above the level of the field. The part exposed measures 6 feet by about 5, and evidently extends under the turf for a much greater distance. This boulder is composed of the grey granite of which so many other boulders in the neighbourhood consist.

"The boulders consist mainly of white granite and of felstone; but many other rocks occur, as may be seen by inspecting the specimens collected. In the neighbourhood of Tettenhall there is a large percentage of granite boulders; but south of here there are very few indeed, the boulders being mainly of felstone. In the Harborne district only one granite boulder has been observed, while there are a hundred or so boulders of other rocks. The contrast between the immense accumulation of granite boulders in the Wolverhampton district and their comparatively small size and rarity around Birmingham is most remarkable."

Granite Boulder on the shore of Barnstaple Bay, North Devon.

Mr. Pengelly reports the following particulars respecting this boulder, upon which the raised beach on the northern side of Barnstaple Bay rests.

So far as it is visible, it measures $7{\cdot}5 \times 6 \times 3$ ft., and therefore, containing upwards of 135 cubic feet, cannot weigh less than 10 tons.

It appears to have been first described by the late Rev. D. Williams, in 1837, as "flesh-coloured, like much of the Grampian granite" and, in his opinion, "neither Lundy, Dartmoor, nor Cornish granite."

In 1866 Mr. Spence Bate, believing that very similar granite existed in Cornwall, expressed the opinion that it was not necessary to go so far as Aberdeen, but that some transporting power must have been required to bring it even from the nearest granite district, and that it without doubt occupied its present position before the deposition of the beach resting upon it.

Recently Mr. Pengelly has been informed that red granite occurs on Dartmoor, and therefore has no disinclination to say, with Mr. Bate, that we need not go as far as Aberdeen to find the source of the boulder, although it nevertheless may have come from the Grampians.

Assuming that the block may have come from Lundy, twenty miles towards the west, or down the valley of the Torridge from the nearest point of Dartmoor, thirty miles off as the crow flies, its transport in either case must have been due to more powerful agencies than any now in operation in the same district. Between Barnstaple Bay and Lundy there are upwards of 20 fathoms of water, a depth at which no wave that ever entered the Bristol Channel would probably ever move the finest sand.

Again, as the highest part of Dartmoor is but 2050 ft. above mean tide, a straight line from it to where the boulder now lies would have a fall of 1 in 77 only, down which the Dartmoor floods would certainly not transport a rock upwards of 10 tons in weight.

The foregoing considerations apply, of course, with at least equal force to the hypothesis of any more distant derivation.

That such a block might have been brought from Dartmoor down the Tor-

ridge to the place it now occupies, had the actual heights been the same as now and the climate as cold as that of Canada at present, will be obvious to every one conversant with that country. It is only necessary to suppose that the block fell from a cliff into a stream where the water was at least sometimes of sufficient depth that when frozen round the mass the latter would be lifted by the buoyancy of the ice. On the breaking up of the ice the floods would transport the rock so long and so far as its ice-buoy was capable of supporting it; and though the distance accomplished in a single journey might, and probably would, be inconsiderable, by a repetition of the process season after season it would become equal to any assigned amount. Blocks of great size have been in this way transported in Canadian rivers for 100 miles or more. Again, were Lundy Island capable of generating a glacier and launching it into the sea as an iceberg, there would be no difficulty in supposing that any number of boulders might be transported thence to the mainland of Devon.

In short, whether the boulder came from Dartmoor or Lundy or any more distant source, it must have been transported by ice-action; and hence its presence where it now lies is good evidence of a climate in this country much colder than that which at present obtains.

From the foregoing considerations it will be seen that, if the mass were ice-borne, the land could not have been higher above the sea during the era of the boulder than it is at present. There is nothing, however, to prevent its being lower. The boulder may have been dropped by an iceberg on or near the spot it now occupies when that spot was covered with deep water. The only stipulation to be made on this point is, that the land which furnished the mass was capable of supplying it with an ice-body. For example, if the boulder was derived from Dartmoor, Devonshire as a whole could not have been any thing like 2050 ft. lower than at present; for that would have been to submerge the entire country, whereas there must have been subaerial land sufficient to form the ice-raft whose buoyancy floated the boulder.

It is hoped that the steps proposed to be taken by the Committee will enable the boulders of one or two districts at least to be systematically mapped, and the existence of other such remarkable boulders as the granite boulder on the shore of Barnstaple Bay to be recorded. Any attempt at systematic classification, however, must necessarily be deferred until the facts are more largely accumulated.

Fourth Report on Earthquakes in Scotland, drawn up by Dr. Bryce, *F.G.S. The Committee consists of* Dr. Bryce, *F.G.S.*, Sir W. Thomson, *F.R.S.*, Geo. Forbes, *F.R.S.E.*, *and* Mr. J. Brough.

The conjecture hazarded in last Report, that "the state of quiescence" therein referred to was "not likely to continue," received a speedy fulfilment. In a postscript to the Report, which was not, however, forwarded in time to be read at the Meeting, it was noticed that "while the Association was in Session at Brighton an earthquake of considerable severity" had "occurred in the Comrie district;" and in April of the present year another

took place in the south of Scotland. Of these an account has now to be given.—A few days after the occurrence of the earthquake, the Member of Committee resident at Comrie communicated with me; and having seen in the newspapers notices of other places where the earthquake had been felt, I entered into correspondence with gentlemen in the various districts. In the end of September I visited several of these districts, and made inquiries in person. From the facts thus made known to me the following account has been drawn up; but before proceeding with it, I have to express my obligations to the following gentlemen for the kind manner in which they complied with my request, and communicated at once all the observations made by themselves, and facts collected from others on whom they could depend:—Dr. Campbell and Rev. James Muir, Bridge of Allan; Rev. William Blair, Dunblane; Mr. J. Stirling Home-Drummond, of Ardoch, Braco; Dr. William Bryce and Mr. David Cousin, both from Edinburgh, the former happening to be at Crieff at the time, and the latter at Bridge of Allan; Mr. P. Macfarlane and Mr. J. Brough, Comrie; Sir David Dundas, of Dunira, Comrie; and Rev. J. E. H. Thomson, B.D., Blair Logie. Dr. Campbell's evidence is especially valuable, as he resided for some time in Upper Strathearn, where earthquakes are of frequent occurrence and were often experienced by him, and as he is in the constant practice of accurate every-day observations of meteorological instruments for a register kept by him at the usual hours. Mr. Macfarlane and Mr. Brough at Comrie possess, of course, like advantages. Mr. Cousin also had the advantage of previous experience in observations of this kind, an earthquake having occurred while he was resident in Algeria. A similar advantage was enjoyed by the Rev. J. E. H. Thomson; at the instant when the shock occurred he was in conversation in his own house with two ladies, one of whom had resided for some years in Valparaiso, where earthquakes are of very common occurrence, as is well known.

The earthquake took place on the 8th of August, 1872, at from 8^m to 10^m past 4 o'clock in the afternoon. The day was warm and perfectly still. In the early part of the day there had been alternations of a cloudy and clear sky; but at the hour mentioned only the western part of the horizon showed cloudy masses, the sky overhead and eastwards was free from cloud of any kind. The barometer rose slightly during the day, from 29·800 at 10 A.M. to 29·975 at 10 P.M. The maximum temperature of the day, in the shade, was 64°·3 F.; the minimum temperature of the night preceding was 53°·8 F., of the night following 51° F. No perceptible change in the temperature or character of the atmosphere as to wind and cloud took place after the shock.

The successive phases, according to almost all the observers, were:—a noise or sound, loud, heavy and rumbling; a shock with a shaking and rattling of objects; and a wave-like motion of the ground. The noise or sound is compared to the sound of thunder, to that made by a heavy waggon on a stony street, to the emptying of a cart of small stones or rubbish, to the noise one hears when under a bridge over which a heavy train is passing. Many who were within doors supposed that a heavy piece of furniture had fallen on the floor of an adjoining room. A clergyman was standing on the hearthrug in his study, and, hearing a sudden noise or crash, imagined a chimney-stack was falling, and rushed instantly into a position of safety. Finding this surmise incorrect, he referred the noise to the fall of a wardrobe in the next room. This surmise also proving incorrect, he went immediately down stairs and found his servants panic-stricken. In the nursery the nurse had rushed to the window and screamed in alarm to her mistress,

who was in the garden. So strong, indeed, and concurrent is the evidence on this point that no doubt can remain about it, in regard to almost all the localities from which communications have been received; the slight discrepancy among the witnesses to the fact may be accounted for by some of them being resident on a soil composed of soft alluvium, and others upon a rocky surface. Some of the witnesses notice that the sound was instantaneously repeated with even greater violence.

The shock instantly followed the noise or sound; and its occurrence was marked in many ways: houses were shaken, doors and windows made to rattle, suspended objects to oscillate; in one house bells were set a-ringing with violence, in another they were strongly agitated; jugs, basins, and water-glasses in bedrooms, apothecaries' bottles, phials, and pots, the glasses in the pump-room at Bridge of Allan Spa were heard to knock against one another and seen to move; a chimney-mirror, loosely fastened, was thrown down; and chimney ornaments were dashed upon the floor.

Next succeeded that most appalling of all the attendant circumstances of an earthquake, the sensation as of a heaving impulse or wave, giving the idea of a crest and declivity, instantly followed by a double vibration, the whole duration being from three to four seconds. The statements of the observers (as made known in the various reports) on whom one feels that most reliance is to be placed from their previous experience, habits of close observation, and the circumstances in which they were placed at the time, all go to show that the undulation came from a direction W. or N.W., some observers making the direction exactly opposite by not distinguishing the first impulse from the recoil or restoration of the wave-surface. One observer, on whom the utmost reliance can be placed, had the most distinct feeling of vertigo or dizziness arising from the undulation, a sensation so strong that a few moments' continuance of it would have produced nausea—a strong testimony to the reality of the wave-motion.

The extent of country throughout which this earthquake was felt is greater than that of any which has occurred since this inquiry was undertaken. The limits are marked by Stirling and Blair Logie on the S.E., and St. Fillans on Loch Earn and Glen Lednock on the N.W. The shock was feebler at these limits than in the parts intermediate, as Bridge of Allan, Dunblane, Greenloaning, Ardoch, and Crieff. In regard to the breadth of country agitated, I have been unable to determine that it extended more than two or three miles from the valley of the Allan Water, the concussions recorded being greater to the east of that valley than in the opposite direction, while in the village of Doune, four miles west, they do not seem to have been noticed. The want of self-recording instruments, the extreme difficulty of determining the exact instant of the occurrence of an event so sudden and startling, render it impossible to attempt any definite statement as to the progress of the wave, which, so far as instrumental indication can serve us, seems to have emanated from near Comrie. All the observers who have attempted to specify an exact time have, to all appearance quite independently, agreed that it was, as above stated, at 10^{m} past 4^{h} P.M. Persons trained to observe, or self-recording instruments, alone can furnish reliable data in such a case for indicating the time occupied in the undulation passing from point to point. The intensity upon the Comrie scale, which ranges from 1 to 10, was of a medium force, about 4.

The geological formation of the tract of country embraced within the above limits varies greatly. The lower part of the village of Bridge of Allan is situated upon the alluvium of the Forth valley, in which, as far up from

the present channel of the river as the streets of the lower part of the village, skeletons of whales have been found. The upper or northern part of the village stands upon a high terrace of Old Red Sandstone, traversed by whin dykes, alongside one of which its famous Spa is discharged. The front of this terrace runs east and west, and forms the former sea-margin, hewed out by the waves of the old estuary, against which the alluvium rests to an unknown depth. The town of Stirling stands upon the south side of the Forth valley, partly on alluvium and partly on a trap ridge erupted through Old Red Sandstone. Eastwards from Bridge of Allan by Blair Logie and Dollar, the Ochill Hills, of which the terrace at Bridge of Allan is the first ridge or step, are composed of the same Old Sandstone, broken through and overlain by a vast body of trap rocks, clay-stones, and porphyries, and present a wall-like front to the Forth valley on the south. They completely cut off the Coal-measures, tilting up the strata at a high angle, altering the coal to the state of coke, shale to Lydian stone, and sandstone to quartzite. Dunblane, Greenloaning and Ardoch, and the wild moorlands N.W. to Crieff are composed of Old Red Sandstone pervaded by traps; and Crieff and Comrie are close upon the junction of the sandstone and old slates of the mountain-region. Glen Lednock and a large area E. of it towards Crieff are occupied by an eruptive granite which sends veins into the slate, and whose outer edge approaches close to the boundary of the slate and sandstone. Whatever the cause of this earthquake may have been—masses of rock falling from the roof of a vast cavern, or a sudden impact of high-pressure steam emanating from the nether depths—all the strata were affected by it, and sent the awful tremor, yet with varying intensity, alike along beds of rock and alluvial strata.

The particulars in regard to the earthquake in the south of Scotland have been kindly supplied by Dr. Grierson and Mr. Henrison, Thornhill, Dumfries, and Mr. J. Shaw, Tyrnon parish. The earthquake took place on the 16th of April, 1873, at 9^{h} 55^{m} P.M. A smart concussion, producing a considerable sound, noise, or crash, as it is variously described, and causing a perceptible movement in fixed objects, and an oscillation of those suspended, was experienced in the parishes of Tyrnon, Glen Cairn, Keir, Penpont, Morton, Closeburn, and Balmaclelland. Doors and windows were made to rattle; there was a sensible vibration of walls and floors in many places; and objects near one another (as glasses and china on shelves) were knocked together. In some cases alarm was shown by the lower animals. But the wave or undulation was not observed with any thing like precision, except in one case, in which a floor was distinctly seen to have such a movement. The late hour, however, was unfavourable for observation on the part of many persons. One only of the observers whose accounts have been furnished to me had any previous experience of earthquakes. This gentleman had resided for some time in the East. Another witness, in every way competent, experienced a repetition of the shock at Thornhill at 2^{h} 46^{m} A.M. on the following morning; but no information regarding this second shock has reached me from any other part of the district.

Ninth Report of the Committee for Exploring Kent's Cavern, Devonshire, the Committee consisting of Sir CHARLES LYELL, *Bart., F.R.S.,* Professor PHILLIPS, *F.R.S.,* Sir JOHN LUBBOCK, *Bart., F.R.S.,* JOHN EVANS, *F.R.S.,* EDWARD VIVIAN, *M.A.,* GEORGE BUSK, *F.R.S.,* WILLIAM BOYD DAWKINS, *F.R.S.,* WILLIAM AYSHFORD SANFORD, *F.G.S., and* WILLIAM PENGELLY, *F.R.S.* (*Reporter.*)

THE Committee, in opening this their Ninth Report, have to state that, since reporting at Brighton in 1872, the work has been continued without intermission, in the manner observed at the commencement. They have to add that whilst it is still conducted, under the Superintendents, by the same foreman (George Smerdon), the second workman (John Farr), believing that the Cavern work was prejudicial to his health, has obtained other employment. Though reluctant to part with so satisfactory a workman, who had faithfully served them for upwards of five years, the Superintendents felt unable to press him to remain under the circumstances; and they had the satisfaction of engaging in his stead a man (John Clinnick) who has proved most efficient and trustworthy.

As in former years, the cavern has been visited by a large number of persons, none of whom, when conducted by the guide only, has been allowed to be taken to the excavations then in progress. The Superintendents have had the pleasure of accompanying the following gentlemen during their visits:—Major-General R. C. Schenck, Minister for the United States of America to England; Lord Clifford, of Chudleigh; Sir R. Anstruther, Bart., M.P.; Rev. Lord Charles Hervey, Rev. G. Butterworth, Rev. Dr. Hanna, Rev. C. N. Kelly, Rev. R. Locker, Rev. T. R. R. Stebbing; Major-General Huyshe, Captain Lovett, Professor W. K. Clifford, Dr. B. Collenette, Professor W. King, Dr. R. Martin, Dr. W. Sharpey, Dr. Topham, Dr. C. Williams, of Burmah; Mons. Wyvekens, of Brussels; and Messrs. A. T. Atchison, W. Babington, N. Bell, of Queensland, C. A. Bentinck, L. B. Bowring, W. Buller, E. L. Corring, of U. S. America, J. A. Curtis, R. D. Darbishire, J. M. Dowie, B. J. M. Donne, E. A. Field, S. Gurney, C. W. Hamilton, H. W. Haynes, of Boston, U. S., C. Sabapathi Jyah, of Madras, J. H. van Lennep, of Holland, C. Lister, P. C. Lovett, C. Meenaeshaya, of Madras, P. H. Mills, A. G. Nathorst, of Lund, Sweden, P. Nind, A. Nesbit, A. Pengelly, of N.W.P. India, H. C. M. Phillips, C. H. Poingdestre, F. P. Purvis, T. Rathbone, Dr. Richardson, R. B. Shaw, British Commissioner, Ladak, J. H. Taunton, P. Watts, and J. E. Wolfe.

A. R. Hunt, Esq., M.A., F.G.S., being about to assist in exploring a small cave on the coast of Kirkcudbright, visited the cavern in August 1873, for the purpose of studying the mode of working.

As in former years, live rats have been observed from time to time in various parts of the cavern. As soon as they are seen, the workmen, having frequently suffered from such visits, set gins for them, and sometimes succeed in taking three or four in a week. On one occasion four (two old and two young ones) were found in the gin together. The adults were the extremes of the series, and, being caught by the neck, were dead; whilst the others were held near the middle, and still alive. Though most prevalent near the entrances of the cavern, they have been frequently observed far in the interior; and very recently they carried off a candle from a spot fully 300 feet from the nearest entrance.

The Long Arcade.—The Committee stated in their last Report, bringing the work up to the end of July 1872, that they were then exploring the branch

of the cavern termed by Mr. MacEnery "The Long Arcade," and sometimes "The Corridor" *, and that they had expended about ten weeks' work on it †. The exploration of this great thoroughfare has been the work of the entire period since that date, and it is still in progress.

The Arcade commences in the south-west corner of the "Sloping Chamber," and, after a length of about 252 feet, in a west-south-westerly direction, and almost in a straight line, terminates in the "Cave of Inscriptions," or "Cul-de-sac." Its height is variable—being in one place not quite 10, and in others upwards of 20 feet, the measurements being taken from the bottom of the excavation made by the Committee. The roof and walls are much fretted and honeycombed, except at one part not far within the entrance, where the fall of a very large block of limestone in comparatively recent times has left edges tolerably sharp and angular.

Omitting blocks of limestone here and there, the surface of the deposit in the Arcade when the Committee commenced its exploration presented but few inequalities; and when they had completed their excavation to the uniform depth of 4 feet below the under surface of the Stalagmitic Floor, and up to the distance of 134 feet from the entrance, the bottom of their section was no more than 40 inches above that at the commencement—a mean rise of no more than 1 in 40. At the point just specified, however, the passage was almost entirely closed with a vast mass of limestone *in situ*, covered in places by thick accumulations of stalagmitic matter, and rising to the roof apparently from the limestone bottom of the Arcade. The only opening in it was a narrow aperture adjacent to the right or northerly wall; and to gain this it was necessary to climb to the height of 8 or 9 feet. It proved to be about 6 feet high, to have a floor of limestone, with occasional stalagmitic incrustations, extending for a length of fully 20 feet; whilst very near the entrance, on the left or southerly side, was the elliptical mouth of a smoothly eroded tunnel, measuring 30 inches in horizontal and 27 in vertical diameter, and having the aspect of a watercourse. Beyond this tunnel, and also on the left side, lay in wild confusion several very large masses of limestone, which had fallen from the roof obviously in remote times; and beyond these the deposit of Cave-earth again presented itself, but at a higher level than before.

Assuming the tunnel just mentioned to have been a watercourse, the stream issuing from it must have had a sudden fall of several feet; and it may not, perhaps, be without interest to state that on excavating the deposits in the Arcade, deep pot-holes were found in the right wall of the cavern, having the position and character such a fall would have produced. The tunnel, fully 60 feet long, terminates in a branch of the cavern known as "The Labyrinth," and in one part of its course is so small as to render it somewhat difficult for even a small man to force his way. It has long been known as "The Little Oven;" and when the cavern was visited by merely the idly curious, it was regarded as an achievement to have made its passage.

One of the results of the work during the last twelve months has been to show that the great mass of limestone, which, as already stated, almost completely closed the Arcade, extended downwards, not to the limestone floor, but merely to the level of the earthy deposits which choked up the passage beneath. The loose and confusedly grouped blocks of limestone already spoken of have been blasted and taken out of the cavern; the blocked-up passage has been reopened and is now the common thoroughfare; the mass of rock overhead has been dignified with the name of "The Bridge," and the excavation has been completed far beyond it.

* See Trans. Devon. Assoc. vol. iii. p. 235 (1869). † Brit. Assoc. Report, 1872, p. 44.

The Arcade is very narrow in proportion to its length. From 17 feet wide at the entrance, it narrows to 5 feet at about 27 yards within, then expanding to 11 or 12 feet, and again contracting until, at 42 yards, it is no more than 6 feet wide, it once more enlarges to an average width of 9 feet, and beyond the Bridge it becomes an irregular chamber, upwards of 30 feet long and about 15 wide. The exploration has been completed to the inner end of this chamber; but the Arcade, again much contracted, has a further prolongation of about 50 feet before reaching the Cave of Inscriptions.

In the left or southerly wall of the chamber just mentioned is the entrance to the Labyrinth, and of another and smaller branch. Towards these the workmen are now directing their labours.

As the earlier explorers had made some excavations here and there throughout the greater part of the Arcade, and thus deprived the Committee of the opportunity of studying it before disturbed by man, the following description, compiled from Mr. MacEnery's manuscripts, may be of interest:—The floor was in great disorder, strewn with rocks having between them in certain places natural reservoirs of water, and in others loose heaps of red marl overspreading the stalagmite and containing fossil bones. The first rhinoceros-tooth found in the cavern was met with in one of those heaps. A peculiarity of this passage was a profusion of a white crumbling substance not unlike half-slacked lime. Rock after rock, on being turned over, presented patches of it on its surface; the loose mud also contained it; and wherever stalagmite had formed between the rocks, it, when ripped up, exhibited large deposits of the same matter. In the crevices of the rock and near the surface of the marl it occurred in balls partly crushed; several balls were found in some instances pressed together, in others uninjured, adhering, and exhibiting the tapering point they had when dropped by the animal; and they were occasionally found singly. There was no doubt that they were coprolites, and no difference between these fæcal deposits and those of the hyæna in Exeter Change, except in the far greater size of the fossil balls. The osseous substance was the same in both; undigested particles of bone and enamel were detected in some of them; and the explorers were led to the conclusion that the Arcade was the chosen resort of the Cavern-hyænas for purposes of cleanliness. In this they were subsequently confirmed by a letter from Captain Sykes to Dr. Buckland, published in the Edin. Phil. Journal*, descriptive of a recent hyæna-cave in India, where, from the almost exclusive accumulation of fæces in particular spots, the writer inferred that certain chambers were dedicated to cleanliness. In these retreats few or no bones occurred. "This description," says Mr. MacEnery, "is in its details quite applicable to Kent's Hole. It appears to have been preserved to us in its actual state as when occupied by the extinct hyæna ...... Whilst reading his letter, I imagined myself reading the history of another, sealed one—the duplicate of Kent's Cave, and not the account of a living hyæna's den." Wherever this substance was found accompanying remains, the latter were invariably broken, and always in the same uniform manner; and none of it was found where they occurred entire. Dr. Buckland, to whom the material was pointed out, gave the Arcade the name of the "Hyænæ Cloaca Maxima."

About halfway in the length of the Arcade, and near the left or southerly wall, three circular hollows were observed in the floor, about 3 feet in diameter, lined down the sides with a thin waving crust. The greasiness of the earth, and the presence of single teeth of bear in different states of preserva-

* Vol. xvi. pp. 378-9 (1827).

tion, at first suggested the idea that they were the beds of that animal, whose habit it is to crouch in particular spots; but the occurrence of charcoal, and other indications of the presence of man, in the vicinity of the hollows were thought rather to lead to the opinion that they were rude hearths or ovens scooped out by savages, around which they collected to cook and enjoy the spoils of the chase *.

Before returning from this digression it may be well to offer a few remarks on two or three points in the foregoing description, on which the exploration now in progress is calculated to throw some light:—

1st. "The loose heaps of red marl" in all probability consisted of material deposited in the era of the Cave-earth, and over which no stalagmite had in those particular spots ever been formed. If, however, they were actually observed, and not merely inferred, to "overspread the stalagmite," the latter, there can be little doubt, was the "Crystalline Stalagmitic Floor," older than the Cave-earth, of which the Committee have found numerous portions in the Arcade during the present year, as well as in other branches of the cavern in previous years, some of them *in situ* and others not.

2nd. The Committee have also found a considerable quantity of coprolitic matter in the Arcade, never, however, more than 12, and rarely more than 6 inches below the surface. This material has been met with in all parts of the cavern wherever the Cave-earth has presented itself, but in no instance in any older or more modern deposit, whether of mechanical or chemical origin. The "Lecture Hall" may perhaps be equally entitled to the name of the *Hyænæ Cloaca Maxima* †.

3rd. There seems no reason to doubt that the "three circular hollows," instead of being the "beds of bears" or "hearths or ovens scooped out by savages," were natural basins in the stalagmite, such as were described in the Committee's Eighth Report ‡; for, to say nothing of the fact that several such basins, even when not more than a very few inches in diameter, have contained charred wood, possibly washed into them in rainy seasons (when such basins are full to overflowing), or perhaps dropped into them accidentally by recent visitors, it is difficult to understand why a savage should have selected for his hearth a spot having nothing to recommend it but its darkness and inconvenience, whilst so many others, in every respect more eligible, were equally at his command. It is noteworthy that, in another part of his memoir, Mr. MacEnery, replying to Dr. Buckland's suggestion that "the ancient Britons had scooped out ovens in the stalagmite," says, "Without stopping to dwell on the difficulty of ripping up a solid floor, which, notwithstanding the advantage of undermining and the exposure of its edges, still defies all our efforts, though commanding the apparatus of the quarry, I am bold to say that in no instance have I discovered evidence of breaches or ovens in the floor" §.

But waiving all this, the Committee, on March 31, 1873, in the course of their work reached a hollow precisely similar to those Mr. MacEnery describes. It was of oval form, 4 feet long, 2 broad, and 9 inches deep, and contained nearly ten gallons of beautifully pure water, but, instead of having been formed by a bear or a human being, it was an example of Nature's handiwork, and in such a position as to render it certain that the foreman of the exploration now in progress was the first human being who ever saw it. It was in the stalagmite covering the deposit, which, as already stated, com-

* See Trans. Devon. Assoc. vol. iii. pp. 235-7, 253-4, 270, 290, and 302-5 (1869).
† See Report Brit. Assoc. 1868, p. 49. ‡ Ibid. 1872, p. 45.
§ See Trans. Devon. Assoc. vol. iii. p. 334 (1869).

pletely filled up the space beneath the Bridge, and was neither discovered nor discoverable until the workmen had advanced 11 feet in the difficult work of reopening this passage.

At the entrance of the Arcade, the Granular Stalagmitic Floor was continuous in every direction for considerable distances. At the right or northerly wall its thickness exceeded that hitherto found in any other part of the cavern, measuring fully 5 feet for a length of about 8 yards; but at the opposite wall it was very rarely more than 2 feet thick. Beyond the point just specified it became gradually thinner, disappearing entirely at 37 feet from it on the right wall, but extending somewhat further on the left. Still further in, such floor as ever existed appears to have been but thin and occasional only, until reaching the Bridge, where it appeared again in considerable volume*. Almost immediately beyond this, there rose from the Stalagmitic Floor a large boss of the same material, in the form of a paraboloid, 2 feet high and 6 feet in basal circumference. As it bore no inscription, and was in the direct line of the work, it was dislodged and broken up, when it was found to consist of pure stalagmite without any extraneous substance. In the earthy deposit adhering to its base were one tooth of bear, a fragment of bone, a ball of coprolite, and a few bits of charcoal. Not far beyond it, but near the right wall of the Arcade, a much larger boss presented itself, having near its summit the inscription "R. L. (or E.) 1604." The mass has been so mutilated by early visitors as to render it uncertain whether the remaining part of the second letter is the lower portion of L or E. The date, however, which is quite distinct, and appears not to have been noticed prior to June 6, 1873, is the oldest at present known in the cavern, though there are several others of the seventeenth century. In excavating, care was taken to leave the mass, as well as the deposit on which it was formed, intact and undisturbed.

The only objects found in the Granular Stalagmitic Floor, in the Arcade, since the Eighth Report was sent in, were a tooth of Hyæna, a few bones and bone chips, a "charcoal streak" about 3 inches above the base of the floor, where its total thickness was 42 inches at one end and 10 at the other, a few pieces of charcoal, and a flint tool. The tool (No. 5990) is of very white flint, having, as shown by an accidental fracture, a very chalk-like texture. It may be described as a hammer-like "core," broad at one end, round-pointed at the other, and formed by several flakes having been struck from the original nodule. Its pointed end shows that it has been used as a hammer. It is 3·2 inches long, 2 inches in greatest breadth, 1·7 inch in greatest thickness, and was found August 19, 1872.

As already stated, remnants of the old (the Crystalline) Stalagmitic Floor occurred *in situ* in various parts of the Arcade, all attached to the right or northerly wall, and above the level of the Granular Floor. The first of them, about 60 feet within the entrance and 6 inches thick, had between it and the Granular Floor an unoccupied space of 15 inches in height. The second, 20 feet further up the Arcade, was a very large mass displaying strikingly the characteristic prismatic crystalline structure; it has suffered much at the hands of visitors; and on one of its fractured surfaces is the date 1836. The

* It is worthy of remark that at the entrance of the Arcade, where the Stalagmitic Floor is so very thick, the drip of water from the roof is at present very copious in rainy seasons, and commences within a few hours of a great rainfall; whilst those parts of the same branch of the cavern where there does not seem to have ever been any stalagmite are perfectly dry at all times and seasons.

third and most important, about 30 feet long, lined the entire lower surface of the mass of limestone forming the Bridge, and extended into the chamber beyond. The less ancient, or Granular Floor, was in some places in contact with it, and in others as much as 8 inches below. Numerous stones and a few fragments of bone (representing the Breccia on which the Old Floor was formed) were found firmly cemented to this, as well as to the first remnant. The progress of the work has not rendered it necessary to remove or diminish either of them.

The deposit below the Granular Stalagmitic Floor was typical Cave-earth to the depth of at least 4 feet *, from the entrance of the Long Arcade to about 24 feet within it, and contained a considerable number of blocks of limestone, several of them requiring blasting in order to be removed. Beyond the point just specified the deposit was everywhere "Breccia" (the oldest deposit the cavern is known to contain), except at most the uppermost foot, which consisted of Cave-earth. The two deposits lay one on the other without, as in the South-west Chamber †, any stalagmite between; and though they are so very dissimilar in composition—the Cave-earth, or less ancient, being made up of small angular fragments of limestone mixed with light-red clay, whilst the Breccia, or older deposit, consists of rounded and subangular fragments of dark-red grit imbedded in a sandy paste of the same colour—it was not always, or, indeed, frequently, easy to detect a well-defined line of separation. Each, however, was, as elsewhere in the cavern, characterized by its distinct fauna—the Breccia containing remains of Bears only without any indication of other genera, whilst the Cave-earth yielded bones and teeth of Hyænas, with their teeth-marks and coprolites, as well as the osseous remnants of the animals usually associated with them.

At the entrance of the Arcade Mr. MacEnery's diggings were carried to a depth of 3 feet below the bottom of the Granular Stalagmite; they gradually became less and less deep until at a distance of 15 feet they ceased. They were resumed at 52 feet, and continued at intervals throughout the entire length of the Arcade so far as the Committee have at present explored. They were, however, on a very limited scale, never exceeding 18 inches, and commonly not more than a foot in depth, did not always extend from wall to wall, and were not continuous. In short, he seems to have contented himself with occasionally digging a small shallow trial pit, and, meeting with no specimens, to have proceeded elsewhere; and this is borne out by his own statement. "As we advanced in the direction of the Long Corridor," he says, "the bones became less and less numerous until they nearly disappeared, rendering it not worth our while to prosecute our researches further in that line" ‡. He must, however, in some instances have broken up portions of the Breccia as well as of the thin layer of Cave-earth lying on it; for, as was his wont, the materials he dislodged were not taken out of the cavern, but merely cast aside; and these, on being carefully examined by the Committee, were found to contain undoubted fragments of the older deposit, with bones and teeth of Bear firmly imbedded in them.

The specimens recovered from this broken ground, and which had been neglected or overlooked, belonged mainly to the Cave-earth. They were 72 teeth, 4 astragali, 5 ossa calcis, 15 phalanges, 1 claw, 3 portions of jaws, 2 vertebræ, 1 portion of skull and 1 of antler, several fragments of bone, and 8

* The excavation is not carried to a depth exceeding 4 feet below the bottom of the granular stalagmite.

† See Brit. Assoc. Report, 1868, pp. 50–52.

‡ See Trans. Devon. Assoc. vol. iii. p. 290.

flint flakes and chips. With them was a portion of an iron hammer, which, on becoming useless, MacEnery or his workmen had no doubt thrown away.

Omitting those of Bear, at least some of which belonged to the era of the Breccia as already stated, the teeth may be distributed as in the following Table:—

TABLE I.—Showing how many per cent. of the Teeth found in the disturbed material in the Long Arcade belonged to the different kinds of Cave Mammals.

Hyæna	70 per cent.	Ox	3 per cent.
Horse	10 „	Elephant	1·5 „
Rhinoceros	10 „	Fox	1·5 „
Deer	3 „		

The flint flakes mentioned above were of little value when compared with many found in the Cave-earth.

Up to the end of August 1873, the Cave-earth which the Committee found intact in the Long Arcade had yielded, when the few mentioned in the Eighth Report (1872) are included, about 280 teeth, which may be apportioned as in the following Table:—

TABLE II.—Showing how many per cent. of the Teeth found in Cave-earth in the Long Arcade belonged to the different kinds of Cave Mammals.

Hyæna	40 per cent.	Deer	2·5 per cent.
Horse	24 „	Megaceros	1·5 „
Rhinoceros	11 „	Elephant	1·5 „
Bear	9 „	Dog?	1·5 „
Fox	5 „	Lion	1·0 „
Pig	3 „	Machairodus	only 1 incisor.

On comparing the foregoing Tables with those in previous Reports, the following facts present themselves:—

1st. That Hyæna is everywhere the most prevalent animal of the Cave-earth era, and is followed by the Horse and Rhinoceros without any considerable variation in their ratios.

2nd. That the Bear is relatively more prevalent in the Long Arcade than in any other part of the cavern explored by the Committee.

3rd. That teeth of Wolf, Badger, Rabbit, Reindeer, and Sheep *—all of which presented themselves in the various branches of the Eastern Division of the cavern—have not hitherto been met with in the Long Arcade.

None of the animal remains found in the Cave-earth during the last twelve months require detailed description or special remark. Many of the bones had been gnawed by the Hyæna; some were much decayed; a few small fragments had been burnt; and one (a phalanx) exhibited marks of disease. The few remains of the Mammoth were those of immature animals; one canine of Lion (No. 6020) was worn almost to the fang; and a right lower jaw of Pig (No. 6098)†, found March 26, 1873, without any other specimen near it, contained eight teeth, some of which had not risen quite above the jaw.

Including the two (Nos. 5819 and 5829) mentioned in the Eighth Report (1872), the Cave-earth in the Long Arcade has, up to the end of August

* The remains of Sheep are probably such as had been recently introduced by foxes and other animals frequenting the cavern.

† This specimen has a very fresh aspect.

1873, yielded 25 flint implements and flakes, without counting those found in Mr. MacEnery's dislodged materials. Though many of them would have attracted a large share of attention a few years ago, a description of a very few will suffice at present:—

No. 6082 is a light-grey flint having a sharp edge all round its perimeter. It is nearly flat on one side, and slightly convex on the other, from which four principal longitudinal flakes have been dislodged. It belongs to the lanceolate variety of implements, is about 3·5 inches long, 1·2 inch in greatest breadth, and ·25 inch in thickness. It was found February 22nd, 1873, without any animal remains near it; and no stalagmite had ever covered the deposit in which it lay.

No. 6086 may be said to belong to the same type; but it is more massive, and is abruptly truncated at each end. It is 3·5 inches long, 1·6 inch in greatest breadth, ·6 inch thick, very concave on the inner face, on which the "bulb of percussion" is well displayed near what may be termed the point; and the outer very convex face has been rudely fashioned. It does not appear to have been used; its edges are quite sharp and not serrated or chipped. It was found March 4, 1873, with a tooth and a gnawed scapula (No. 6086).

As in all other parts of the cavern in which it has occurred, the Breccia in the Long Arcade differs from the Cave-earth not only in the mineral and mechanical characters of its materials, as already pointed out, but also in the absence of those films of stalagmite which so frequently invested bones and stones at all levels in the less-ancient accumulation.

The deposits resembled each other in being entirely destitute of any approach to a stratified arrangement; and the incorporated fragments of stone lay with their longest axes in every possible direction.

Up to the end of August 1873 there had been found in the Breccia in the Long Arcade upwards of fifty teeth, together with a considerable number of bones, of Bear. As they were much more brittle than those found in the Cave-earth, probably from their highly mineralized condition, and almost invariably occurred where the materials were firmly cemented together, it was impossible to prevent their being injured in the process of extraction. Not unfrequently bones or teeth were found broken but having the parts in contact and juxtaposition in the concrete, showing that they had been broken where they lay and where they were found. Beyond a few teeth still occupying portions of jaws, the remains did not lie in their natural anatomical order; and isolated teeth frequently presented themselves completely encased with Breccia. In no instance was there any thing like an approach to the elements of a complete skeleton, or distinct portion of one, lying together.

The only noteworthy specimens are a left lower jaw (No. 6127) containing two teeth, found June 18, 1873, and a palate (No. 6133) with the greater part of the upper jaw, in which were four molars and the two canines. This fine specimen was found June 25, 1873, and with it two other canines and a few fragments of bone.

It is perhaps worthy of remark that as no trace of *Machairodus* has been found in either of the deposits since the Eighth Report (1872) was presented, the Committee can only repeat that, so far as the evidence goes at present, that great Carnivore was a member of the fauna of the Cave-earth era, but not of that of the Breccia.

In their Eighth Report (1872) the Committee stated that they had

found two flint implements (Nos. 5900 and 5903) in the Breccia in the "Southern Branch" of the "Charcoal Cave;" and they pointed out the important bearing of the fact on the question of Human Antiquity *. They have now the pleasure of reporting the discovery, during the last twelve months, of seventeen additional implements, flakes, and chips in the same deposit in the Long Arcade; and they now propose to describe the most striking specimens.

No. 6022 is a fine kite-shaped flint tool, 5·1 inches long, 2·6 inches in greatest breadth, and 2 inches in greatest thickness. On one side, especially at the butt-end, it is very convex; on the other it may be said to have a tendency to flatness; but as this inner face consists of two principal planes or facets sloping in opposite directions from a transverse ridge about midway in its length, the flatness is not strongly pronounced. At the butt-end, on the convex face, it retains much of the original surface of the nodule, and shows that it was made from a well-rolled pebble. The rest of the surface has a somewhat orange-coloured ferruginous tint, derived, no doubt, from the matrix in which it was found. On one or two small facets near the point, however, this tint does not appear, but the true whitish colour is displayed. A small chip has been unfortunately struck from it by the tool of the workman and thus displays the interior, which is of the same colour as the facets just named, but differs from them in being somewhat granular, whilst they are quite smooth. Within the substance of the implement and near the point there is a small irregular quartz pebble, apparently the nucleus around which the siliceous matter accumulated. This specimen was found on November 27, 1872, at a depth of 16 inches in the undisturbed Breccia under a block of limestone measuring 24 × 14 × 14 inches, adjacent to the left wall of the Arcade, and 73 feet from its entrance. No animal remains or other objects of interest were found near it.

No. 6025 may be described as a fine implement, rudely foot-shaped, 5·4 inches long, 2·5 inches in greatest breadth, and 1·7 inch in greatest thickness. It has undergone a considerable amount of chipping, is very convex on one face, has a tendency to flatness on the other; and no portion of the original surface of the nodule remains on it. It is of a yellowish drab colour, and has a patina on the greater part of its surface. It was found on December 9, 1872, not quite a foot deep in the Breccia, very near the left wall of the Arcade, about 86 feet from its entrance, and without any animal remains accompanying it.

No. 6081 is an orange-coloured flint implement, rudely elliptical in outline, very massive, about 6 inches long, 3·7 inches in greatest breadth, 2 inches in greatest thickness, very convex on one face, with a tendency to flatness on the other, has a great number of facets on each face, but with portions of the original crust of the nodule here and there. On the flatter face there is a rugged elliptical hole, nearly central, ·9 inch long, ·65 inch broad, and ·7 inch deep; but instead of being artificial is structural, as the original crust of the flint extends into it from a neighbouring patch on the face of the tool. This specimen was found in the third-foot level of Breccia, without any organic remains near it, on February 14, 1873, at about 122 feet from the entrance of the Arcade.

No. 6103 is a coarse chert tool about 4 inches long, 2·3 inches in greatest breadth, 1·6 inch in greatest thickness, very convex on both faces, and worked to an edge all round. A large amount of labour has been bestowed in fashioning it; and no part of the original surface of the nodule remains. It was found, without any animal remains near it, May 7, 1873, in the

* Report Brit. Assoc. 1872, pp. 43–44.

fourth- or lowest-foot level of the Breccia, a small portion of which adheres to it.

No. 6110, apparently of the same variety of chert, is rudely semilunar in form, 2·9 inches long, 1·8 inch in greatest breadth, and 1·2 inch in greatest thickness. It has a thin edge on its rectilineal margin, but attains its greatest thickness at its curvilineal margin, and seems to have been used as a scraper. It was found May 28th, 1873, at about 166 feet from the entrance of the Arcade, without any organic remains near it, in the second-foot level of the Breccia, traces of which still remain on it.

No. 6128 may be said to be at once a rude parallelogram and an oval. It is 2·9 inches long, 1·9 inch in greatest breadth, ·8 inch in greatest thickness, slightly and irregularly concave on one face, and convex on the other. Its greatest thickness is very near one margin, whence it slopes to a comparatively thin edge on the other. Its internal structure is somewhat chalk-like; and it has probably been somewhat rolled. It was found about 172 feet from the entrance of the Arcade in the first-foot level of the Breccia, without any noteworthy objects near it, on June 18, 1873.

No. 6129 is a fine implement of the same form as No. 6022. It is 5·5 inches long, 2·8 inches in greatest breadth, 1·6 inch in greatest thickness, approximates flatness on one face, and is very protuberant on the other, which retains a portion of the original surface of the nodule. It is of a somewhat coarse cherty structure and a dull pinkish colour. It was found on June 20, 1873, in the fourth-foot level of the Breccia, almost immediately under No. 6128, but 3 feet deeper in the deposit, and without any bones or teeth near it.

No. 6139 is a faint pink unshapen lump of flint, the surface of which has nevertheless been artificially produced. It may be a "core," or an implement spoiled in the attempt to make it. It was found about 128 feet from the entrance of the Arcade, without any objects of interest near it, in the third-foot level of the Breccia, on July 2, 1873.

No. 6174, like Nos. 6110 and 6128, is thickest at one margin, and slopes thence to an edge at the other, and, like them, has probably been used as a scraper. It is 2·6 inches long, 1·6 inch in greatest breadth, and 1·1 inch in greatest thickness. It was found, with a tooth of Bear and a few bones, on August 19, 1873, in the second-foot level of the Breccia, at about 128 feet from the entrance of the Arcade.

The facts disclosed since the Committee sent in their Eighth Report, and which have been described above, point to certain conclusions and suggest a few speculations to which it may not be out of place to call attention.

The remnants of Crystalline Stalagmitic Floor in the Long Arcade, with stones still cemented to their under surfaces, like those in the Gallery opening out of the Great Chamber* and in the branches of the Charcoal Cave†, are capable of but one explanation. They point to a time when the Breccia was introduced; and they mark or define the height it reached; they show a subsequent period when this accumulation was sealed up with a calcareous sheet of which they are the remnants; and they make known the facts that a portion of the Breccia was dislodged, and vast masses of the Floor which covered it were broken up. This was followed by the introduction of the Cave-earth, and that by the formation of another Floor of Stalagmite, differing from the former in being granular instead of crystalline.

That the Breccia was derived from without the cavern is certain from the

* See Report Brit. Assoc. 1867, pp. 4–5. † Ibid. 1872, pp. 41–42.

fact that the Cavern-hill contains no rock capable of furnishing the materials composing it. Such materials, however, are derivable from loftier adjacent eminences.

That these materials were introduced with comparative rapidity is probably indicated by the paucity, to say the least, of angular fragments of limestone, as well as of films of stalagmite on the stones or bones, both of which the walls and roof of the cavern would in all probability have supplied during a protracted period.

That the conditions of the surface of the district adjacent to the cavern must have changed between the period of the Breccia and that of the Cave-earth, is manifest from the fact that such materials as formed the staple of the earlier deposit did not find access during the later.

The scantiness of the Cave-earth in the Arcade, and its immense volume in the eastern division of the cavern, especially in the branches of it into which the external entrances open, as well as those immediately adjacent, indicates that this deposit was derived largely, if not entirely, from external sources, and not from the wasting of the walls and roof of the cavern, since there is no reason to suppose that the rate of disintegration or decomposition would differ so very greatly in the different Chambers and Galleries. It may be worthy of remark, moreover, that, all other things being the same, the thickness or depth of a deposit derived from the waste of the walls and roof of a chamber must be greatest in the narrowest chamber, whilst the reverse obtains in the present case.

A glance at the implements from the two deposits shows that they are very dissimilar. Those from the Breccia are much more rudely formed, more massive, have less symmetry of outline, and were made by operating, not on flakes purposely struck off from nodules of flint or chert, as in the case of those from the Cave-earth, but directly on the nodules themselves, all of which appear to have been obtained from accumulations of supracretaceous flint-gravel, such as occur about four miles from the cavern. There seems no doubt, then, that the Breccia men were ruder than those of the Cave-earth; and this is borne out by the fact that whilst the men represented by the later deposit made bone tools and ornaments—harpoons for spearing fish, eyed needles or bodkins for stitching skins together, awls perhaps to facilitate the passage of the slender needle or bodkin through the tough thick hides, pins for fastening the skins they wore, and perforated Badger's teeth for necklaces or bracelets—nothing of the kind has been found in the Breccia. In short, the stone tools, though both sets were unpolished and coeval with extinct mammals, represent two distinct civilizations.

It is equally clear that the ruder men were the more ancient; for their tools were lodged in a deposit which, when the two occurred in the same vertical section, was invariably the undermost. In fact the Breccia in which each of the implements was deposited actually had Cave-earth lying on it.

That the chronological interval separating the two deposits, tools, men, and eras was a great one is indicated by the several facts which have been enumerated. The altered condition of the surface of the adjacent district manifested by the dissimilar mineral and physical characters of the deposits, the sheet of Crystalline Stalagmite which usually separated them and sometimes attained a thickness little short of 12 feet, the destruction of great masses of this sheet, the dislodgment of a considerable portion of the Breccia on which it was formed, and the distinctness of the two Cavern-faunæ are phenomena very significant of an amount of time incapable of compression within narrow limits.

When the cavern-haunting habits of the Hyæna are remembered, it can scarcely be unsafe to conclude from the absence of any trace of him in the Breccia that he was not an inhabitant of Britain during the era of that deposit. The same argument can by no means be applied with equal force to the Horse, Ox, Deer, &c., whose absence is equally pronounced; for it may be presumed that their bones occur in caverns at least mainly because their dead bodies were dragged there piecemeal by the Hyæna; and this could not have occurred before his arrival. The Ursine remains met with in the Breccia present no difficulty, as the Bear, like the Hyæna, is a cave-dweller*. The fact that though he was not a member of the British fauna during the era of the Breccia, he had become very prevalent during that of the Cave-earth, may probably be taken as indicating that after, but not during, the period of the Breccia, Britain was a part of continental Europe, and thus rendered his arrival possible. If this be admitted, it follows that the early men of Devonshire saw this country pass from an insular to a continental state, and again become an island.

The Superintendents of the work, struck with the great development of the Breccia in the innermost parts of the cavern, as well as with the numerous remains of Bear which it contains, are strongly inclined to the opinion that there must be an external entrance hitherto unsuspected, and at present choked up, in the direction in which the work is progressing. It must be admitted that this would solve several problems of interest; but the complete exploration of the cavern can alone show whether or not such an entrance exists.

The Flint and Chert Implements found in Kent's Cavern, Torquay, Devonshire. By W. PENGELLY, *F.R.S., F.G.S.*

[A Communication ordered by the General Committee to be printed *in extenso*.]

THOUGH there are said to be persons capable of believing that the so-called flint and chert implements, found in Kent's Hole and other caverns, are merely natural products, it is not my intention in this brief paper to say one word on that question. It has been treated so fully and so ably by various writers as to deprive me of any pretence for attempting to add any thing to the literature of the subject, and also of any hope that such additions as I might be able to make would convince those still remaining in a sceptical

* Dr. A. Leith Adams, M.A., F.R.S., F.G.S., so well known as a naturalist and cavern-explorer, has been so good as to favour me with the following note on the habits of the Brown Bear of the Himalayas:—"The Brown Bear of the Western Himalayas hybernates, choosing chiefly caverns and rock-crevices, which it abandons in spring to wander about; but old individuals, when no longer equal to the same amount of exertion, take to a secluded life, and usually select a cavern on a rocky mountain-side, at the base of which there is abundant verdure and shade, with a pool or spring, where they bathe frequently or recline during the heat of the day to escape annoyance from insects. Such retreats are easily discovered by the animal's footprints on the soil and turf. They are seen like steps of stairs leading from the pool in the direction of the den, being brought about by the individual always treading in the same track. Thus these patriarchs or hermit bears spend their latter years in one situation, pursuing the even tenor of their ways to the little stream or pond below, and grassy slopes to feed on the rank vegetation, returning regularly to the caverns where they end their days."—See *Wanderings of a Naturalist in India, Western Himalayas, and Cashmere*, pp. 232–241 &c.

state. My present object is to call attention to the fact that whilst all the noteworthy flint and chert implements which Kent's Hole has yielded are unpolished, and all found with the remains of the extinct Cave mammals, they belong to two distinct classes, eras, and states of civilization.

It may be well at the outset to describe briefly the successive deposits and their contents met with during the exploration of the cavern by the Committee appointed by the British Association in 1864, whose labours have extended without interruption from March 1865 to the present time, and are still in progress. They are as follow:—

1st, or uppermost, Blocks of limestone, from a few pounds to upwards of one hundred tons each, which had fallen from the roof, from time to time, and were occasionally cemented together with stalagmite.

2nd. Beneath and between the blocks just mentioned lay a dark-coloured mud, from 3 to 12 inches thick, and known as the *Black Mould*.

3rd. A Stalagmitic Floor of granular texture, varying from an inch to upwards of 5 feet in thickness, and frequently containing large blocks of limestone similar to those mentioned above. This was known as the *Granular Stalagmite*.

4th. An almost black layer, composed mainly of small fragments of charred wood, and about 4 inches thick. This, termed the *Black Band*, was a local deposit occupying an area of about 100 square feet, and, at its nearest approach to it, about 32 feet from one of the entrances to the cavern.

5th. An accumulation of light-red clay, containing:—on the average, about 50 per cent. of small angular fragments of limestone, with occasional blocks of the same substance as large as those lying on the surface as already stated; large isolated masses of stalagmite having a very crystalline texture; subangular and rounded fragments of quartz and red grit, derivable not from the Cavern hill, but from the adjacent and greater heights; and a very few granitic pebbles. This, known as the *Cave-earth*, was usually of unknown depth, but it certainly, and perhaps greatly, exceeded 4 feet in most cases.

6th. Wherever the bottom of the Cave-earth was reached, however, there was found beneath it a Floor of Stalagmite, having a crystalline texture identical with that of the detached isolated masses incorporated in the Cave-earth as just stated. This, designated the *Crystalline Stalagmite*, was in some instances little short of 12 feet thick.

7th. Below the whole there lay, so far as is at present known, the lowest and oldest of the Cavern deposits, consisting of subangular and rounded pieces of dark-red grit, imbedded in a sandy paste of the same colour. This, the thickness of which is unknown, is denominated the *Breccia*.

The lumps of stalagmite and fragments of grit found imbedded in the Cave-earth were undoubtedly portions of the two older deposits (the Crystalline Stalagmite and the Breccia), and show that these accumulations had been broken up by natural agency before the introduction of the Cave-earth, and that they were formerly of greater volume than at present.

Excepting the overlying blocks of limestone, No. 1, all the deposits just described contained remains of animals. In the Black Mould, or most modern, they were those of species still existing, and almost all of them now occupying the district. They were man, dog, fox, badger, brown bear, *Bos longifrons*, roe-deer, sheep, goat, pig, hare, rabbit, water-rat, and seal. In the Granular Stalagmite, Black Band, and Cave-earth, and especially the last, extinct as well as recent animals presented themselves, the Cave-hyæna being the most prevalent, but followed very closely by the horse and rhinoceros. Remains of the so-called Irish elk, wild bull, bison, red deer, mammoth, badger, the cave-,

grizzly, and brown bears, were by no means rare; those of the cave-lion, wolf, fox, and reindeer were less numerous; and those of beaver, glutton, and *Machairodus latidens* were very scarce. The presence of the hyæna was also indicated by his coprolites, by bones broken after a manner still followed by existing members of the same genus, and by the marks of his teeth found on a very large proportion of the osseous remains in the cavern. In the lower deposits (the Crystalline Stalagmite and the Breccia) remains of animals were less uniformly distributed. In some places there were none throughout considerable spaces, whilst in others they were so crowded as to form 50 per cent. of the entire deposit. So far as is at present known, they were exclusively those of bear. Not only were there no bones of hyæna, there were none of his fæces, none of his teeth-marks, and no bones fractured after his well-known fashion. Remembering his cavern-haunting habits, it may in all probability be safely concluded that the era of the Crystalline Stalagmite and of the Breccia it covered, was prior to the advent of the hyæna in this country. The same inference cannot with certainty be drawn with respect to the horse, ox, deer, &c., whose absence is equally pronounced; for it may be presumed that their bones occur in caverns simply because their dead bodies were dragged there piecemeal; and this would not have occurred, even though they had occupied the country, before the arrival of the great bone-eating scavenger which we call the cave-hyæna. The bear, being a cave-dweller, presents no difficulty.

The bones found in the uppermost deposit, the Black Mould, were of much less specific gravity than those in the lower accumulations, and were generally so light as to float in water. Those in the Cave-earth and Breccia had lost their animal matter, and adhered to the tongue when applied to it, so as frequently to support their own weight; but those from the Breccia (the lowest or oldest deposit) were much more mineralized and brittle than those found in the Cave-earth, and usually emitted a metallic ring when struck.

The following general statements may be of service here, by way of recapitulation, before proceeding further:—

1st. Omitting the overlying blocks of limestone and the local Black Band, the cavern contained three distinct *mechanical* accumulations:—the Black Mould, or uppermost, or most modern; the Cave-earth; and the Breccia, or lowermost, or most ancient. Their mode of succession was never transgressed; and the materials of which they consisted were so very dissimilar as to characterize them with great distinctness.

2nd. These three accumulations were separated by two distinct floors of Stalagmite having strongly contrasted characters. That between the Breccia below and the Cave-earth above it was eminently *crystalline*, whilst that dividing the Cave-earth from the Black Mould was *granular*.

3rd. Animal remains occurred in all, but were much more abundant in the mechanical deposits than in the Stalagmites.

4th. The period represented by the Breccia and Crystalline Stalagmite (the most ancient period) may, as a matter of convenience, and so far as the cavern is concerned, be termed the *Ursine* period, these deposits having yielded remains of bears only. It must be understood, however, that bears are represented in all the deposits.

5th. The period of the Cave-earth and Granular Stalagmite may be denominated the *Hyænine* period, the remains of hyæna being restricted to these deposits and being more prevalent than those of any other genus.

6th. The period of the Black Mould (the most modern period) may be

called the *Ovine* period, remains of the sheep being restricted to this accumulation.

7th. The bones of each period were distinguishable by their physical condition—those from the Black Mould being lighter, and those in the Breccia more mineralized, than the products of the Cave-earth.

Flint and chert implements presented themselves in each of the *mechanical* deposits; and, as in the case of the bones, those belonging to any one were easily distinguishable from those of the other two.

The implements of the Black Mould, the uppermost deposit, were of the ordinary colour of common flints. They were mere flakes and "strike-lights," the latter probably used and cast aside or lost by those who during a long period, and before the invention of lucifer-matches, acted as guides to the cavern. All further notice of them may be omitted as not being noteworthy.

Omitting mere flakes, of which there were great numbers, the principal flint implements found in the Cave-earth were ovoid, lanceolate, and tongue-shaped, produced by fashioning, not flint nodules, but flakes struck off them. They were of comparatively somewhat delicate proportions, usually of a white colour and porcellaneous aspect, and had, through metamorphosis, a granular chalk-like internal texture.

Flint implements were not the only human industrial remains found in the Cave-earth, as it had yielded a bone needle with a well-formed eye, three bone harpoons (one of them barbed on both sides, and the others on one only), a bone pin, a bone awl, and a badger's tooth having its fang artificially perforated for the purpose apparently of being strung with other objects to form a necklace or bracelet, thus indicating that the Cave-dwellers of the *hyænine* period occupied themselves in making ornaments as well as objects of mere utility.

The implements from the Breccia are much more rudely formed, more massive, less symmetrical in outline, and have been made by operating, not on flakes, but directly on nodules derived from supracretaceous accumulations, and generally retain some traces of the original surface. One of the specimens, however, is a mass of flint which may have been a "core" from which flakes were struck, or, what seems not less probable, the useless result of an abortive attempt to make a tool.

No such implements have been found in the Cave-earth, nor have any of the comparatively slender, symmetrical, and well-finished tools of the more modern deposit been met with in the more ancient. They are by no means so abundant as those of the Cave-earth; that is to say, a given volume of Breccia does not yield so many implements as an equal volume of the more modern accumulation. Whether equal periods of time are represented by equal volumes of deposit in the two cases, or whether equal periods of time represent equal numbers of human cave-dwellers or tool-makers in the two eras, are questions into which it is not possible to enter at present. Omitting rude flakes and mere chips, as well as the "core" just mentioned, the Breccia up to this time has yielded no more than eleven specimens. It must be remembered, however, that the time during which the Committee have been excavating Breccia is comparatively very short.

That the implements from the Breccia belong to a ruder age than those from the Cave-earth may probably be safely concluded from their much ruder form and finish, and also, if negative evidence be trustworthy, from the entire absence of bone tools of any kind. That they belong to an earlier period is obvious from the position they occupied: they were lodged in a

deposit which, when the two were found in the same vertical section, invariably underlay the Cave-earth. In fact, the Breccia in which every one of the tools was found actually had Cave-earth vertically above it.

That the chronological interval which separated the era of the older ruder tools from that of the others was a great one is indicated by several facts :—

1st. The conditions under which the two accumulations were deposited on the same area were so dissimilar, that the older mass consisted of subangular and rounded pieces of grit imbedded in a sandy paste produced by the attrition and disintegration of the same materials, whilst the less ancient deposit was formed of angular fragments of limestone incorporated in fine clay.

2nd. The two deposits were separated by a sheet of crystalline Stalagmite, in some places almost 12 feet thick.

3rd. After the Breccia had been sealed up with the Stalagmite just mentioned, the latter was, in extensive parts of the cavern, broken up by some natural agency, and much of the Breccia was dislodged, before the first instalment of Cave-earth was introduced.

4th. The faunæ of the two periods were also dissimilar: that of the Breccia did not include the hyæna, which played so important a part in the cavern-history during the Cave-earth period, and whose agency, next to that of man, has made cavern-searching an important branch of science. His absence in the one fauna and his presence in the other, may probably be safely taken as indicating that after, but not during, the period of the Breccia, Britain was connected with the continent, and thus rendered it possible for him to reach this country. In other words, the earliest human Devonians at present known to us saw this country an island as at present; but it had become part of continental Europe before the arrival of the Cavern-hyæna amongst their descendants.

Without attempting to estimate the amount of time represented by the less ancient Cavern deposits (the Black Mould, the Granular Stalagmite, and the Cave-earth), it seems impossible to doubt that the period indicated by the formation of the Breccia and the Crystalline Stalagmite, and the destruction and dislodgment of much of them, must be at least as great. In other words, and speaking only for myself, however far back in time the fabricators of the Cave-earth tools take their stand, I cannot hesitate to place those of the implements of the Breccia as much further back. Most of us remember, and perhaps few of us can be surprised at, the alarm occasioned by the antiquity of man made known by the researches in Brixham Cavern in 1858; and now I cannot doubt that cavern-researches growing out of those just mentioned make a reasonable and irresistible demand to have that antiquity at least doubled.

What may be the relation of the Cave-men whose eleven tools are now before us to preglacial times, I will not presume to say; but I cannot divest myself of the idea that a complete exploration of Kent's Hole is calculated to give a definite reply to that question.

Meanwhile it may not be without interest to remark that, up to the present time, as the Cavern exhibits to us more and more ancient men, it shows us that they were ruder and ruder as we proceed into antiquity. The men of the Black Mould had a great variety of bone instruments; they used spindle-whorls, and made pottery, and smelted and compounded metals. The older men of the Cave-earth made a few bone tools; they used needles, and probably stitched skins together; but they had neither spindle-whorls, nor pottery, nor metals; their most powerful weapons were made of flint

and chert, many of them symmetrically formed and carefully chipped; but it seems never to have occurred to them to increase their efficiency by polishing them. The still more ancient men of the Breccia have left behind them not even a single bone tool; their flint implements are rude and massive, show but little attempt at regularity of outline, and are but rudely chipped.

Report of the Committee, consisting of Dr. Gladstone, Dr. C. R. A. Wright, *and* W. Chandler Roberts, *appointed for the purpose of investigating the Chemical Constitution and Optical Properties of Essential Oils. Drawn up by* Dr. Wright.

Since the last Meeting of the Association, a number of points connected with the experiments then made have been fully worked out, and some interesting information gained on the subject of isomerism among bodies of the terpene class and their derivatives.

The action of nitric acid on the terpene of turpentine-oil has been shown by Schwanert to give rise to a non-crystalline acid (*camphresic acid*), which is tribasic, and is expressed by the formula $C_{10}H_{14}O_7$; the terpene of nutmeg-oil has been found to give rise by similar treatment to oxalic acid, and an acid resembling honey when freshly prepared, but solidifying to a crystalline mass on standing for some months. This has been termed *Myristisic* acid; its analysis agrees with the formula $C_{20}H_{26}O_{16}$, $2H_2O$, the $2H_2O$ being lost at 100° C., and 6 of the 26 proportions of hydrogen being replaceable by calcium. Simultaneously, toluic and terephthalic acids are produced by the oxidation of the cymene naturally admixed with the terpene.

Hesperidene, the terpene of orange-oil, when treated in the same way, gives neither toluic nor terephthalic acid; oxalic acid, and an acid much resembling myristisic acid but containing more oxygen, are formed; this acid, which has been termed *Hesperisic acid*, is expressed by the formula $C_{20}H_{26}O_{17}$, $2H_2O$, the $2H_2O$ being lost at 100°, and 6 proportions of hydrogen being replaceable by calcium.

From the character of the oxidation products, it thus seems that the terpenes of turpentine, nutmeg-oil, and orange-oil are not identical, but only isomeric—a conclusion already drawn from their different physical properties (*e.g.* their boiling-points, 160°, 163°-164°, and 178° respectively); turpentine-oil when oxidized also gives rise to small quantities of terephthalic acid; this, however, without doubt arises from the presence of cymene in ordinary turpentine (*vide infra*).

Although hesperidene contains no cymene ready formed (as proved by the non-formation of toluic and terephthalic acids from it by oxidation, and the failure in extracting cymene by a method which readily yields that hydrocarbon when applied to oil of turpentine or to the mixed hydrocarbons of nutmeg-oil) it is nevertheless closely related to that substance; by cautiously adding two equivalents of bromine to one of hesperidene, a dibromide is formed (with evolution of heat): on attempting to distil this product it breaks up into hydrobromic acid and cymene, thus,

$$C_{10}H_{16}Br_2 = C_{10}H_{15}Br + HBr = C_{10}H_{14} + 2HBr.$$

An intermediate unstable body, $C_{10}H_{15}Br$, appears to be formed; but three or four distillations suffice to break up the *dibromide* almost wholly into cymene

and hydrobromic acid: a small quantity of non-volatile resinous matter is formed; otherwise the yield of cymene approaches the theoretical quantity.

Precisely the same result takes place on adding two equivalents of bromine to the lowest-boiling fraction of nutmeg hydrocarbons (boiling at 163°–164°, and containing 10 to 12 per cent. of cymene ready formed), with these differences—that the yield of cymene is much less in this case, half the terpene present being converted into non-volatile black resinous substances, and, secondly, that much more heat is generated by the union of a given quantity of bromine with the nutmeg-terpene than is with the same amount of hesperidene. The higher the boiling-point of the original terpene, the more readily does its dibromide break up into cymene and hydrobromic acid: thus hesperidene dibromide gives not far from the theoretical yield; nutmeg-terpene dibromide about 50 per cent. only; whilst turpentine dibromide is but little affected by heat alone (Oppenheim), although it does yield some cymene by this treatment (Greville Williams; Barbier),—the boiling-points of the three terpenes being respectively 178°, 163°–164°, and 160°.

The same difference between hesperidene and the nutmeg-terpene is noticeable when equal quantities of the two are shaken up with their own bulks of strong sulphuric acid: the terpenes are polymerized, much heat being evolved, this evolution being much greater in the case of the nutmeg-terpene. Attempts to estimate quantitatively the difference in heat-development did not lead to any trustworthy results, beyond indicating the bare fact that there is a great difference.

Taking into consideration these circumstances, together with the researches of Fabre and Silbermann on the heats of combustion of acids of the acetic series and compound ethers isomeric with them, and on the hydrocarbons of the olefine family, it appears extremely probable that the higher the boiling-point of any member of a series of isomerides, the greater is the "affinity" between its constituent elements (*i. e.* the greater is the work performed in their union), and consequently the less is what may be termed the *intrinsic chemical energy* of the compound (*i. e.* the less work can be obtained by the conversion of a given weight of the compound into other constant products); or in other words, *the heat of combustion of an isomeride of higher boiling-point is less than that of one of lower boiling-point.* It has not yet been found practicable to test this point in the case of the isomeric terpenes, first, on account of the difficulty of obtaining perfect combustion, and other experimental errors, and, secondly, on account of the difficulty in getting terpenes free from cymene to operate on. It is, however, hoped that some satisfactory evidence on this head may be obtained whenever the experiments on various oils &c. have disclosed the existence of a terpene which, like hesperidene, appears to be one single *homogeneous* body of formula $C_{10}H_{16}$; in the mean time the author cordially invites all chemists who are interested in this point, so vitally connected with the subject of isomerism, to submit it to the test of experiment in any cases that may seem to them promising.

In order to make sure that the cymenes thus obtained from hesperidene and nutmeg-terpene are identical with the ordinary cymene from cummin-oil, a careful examination was made of specimens of cymene derived from every available source. Fittig, Köbrich, and Jilke have shown that the cymene obtained from camphor by the action of zinc chloride is mixed with a large number of other substances; this circumstance appears to have misled Kekulé and others into the belief that there are *two* distinct isomerides, a conclusion entirely negatived by the experiments described below.

The cymenes from the dibromides obtained as above were purified by frac-

tional distillation, and their optical properties were determined by Dr. Gladstone; their corrected boiling-points were accurately determined; combustions were made of them; and the products of their oxidation by chromic acid were carefully studied. Other cymenes from the undermentioned sources were also submitted to the same treatment.

A. *Cymene from Myristicol by the action of Zinc Chloride.*—When myristicol is treated with solid zinc chloride in a small retort, a powerful action takes place before the boiling-point is reached, water and cymene distil over, and a non-volatile resinous mass is left in the retort. This resinous mass appears to be formed by the reaction

$$2n(C_{10}H_{16}O)=nH_2O+(C_{20}H_{30}O)_n.$$

After purification by shaking up with sulphuric acid and distillation over sodium, the distillate yields tolerably pure cymene.

B. *From Myristicol by the action of Phosphorus Pentachloride.*—As stated in last year's Report, myristicol, when treated with phosphorus pentachloride, undergoes the reaction

$$PCl_5+C_{10}H_{16}O=POCl_3+HCl+C_{10}H_{15}Cl;$$

the resulting body, $C_{10}H_{15}Cl$, breaks up on heating into hydrochloric acid and tolerably pure cymene.

C. *From Camphor by Phosphorus Pentachloride.*—Louguinine and Lippmann have shown that the chlorinated body, $C_{10}H_{15}Cl$, obtained by Gerhardt and by Pfaundler by the action of phosphorus pentachloride on camphor, breaks up readily on continued distillation, forming hydrochloric acid and apparently pure cymene; their experiments were repeated, and their results confirmed in every respect.

D. *Cymene from Hydrocarbons of Nutmeg-oil (preexisting).*—As stated in last year's Report (Appendix), by treating the lowest-boiling fraction (163°–164°) of nutmeg hydrocarbon with strong sulphuric acid, the terpene is polymerized; the resulting mass, when diluted with water and distilled, furnished a crude cymene, which may be purified by repetition of the process and fractional distillation over sodium.

E. *Cymene preexisting in Turpentine.*—Turpentine-oil was distilled over sodium, and found to boil at 156°–159°; on treatment with sulphuric acid &c., about 3 per cent. of cymene was isolated.

Recently Riban has published some experiments almost identical in their result with the foregoing observations (made in September and October 1872); he, however, concludes that the cymene is derived from the terpene through the oxidation of H_2 by the sulphuric acid. The author dissents from this conclusion for various reasons, the two chief ones of which are that hesperidene yields no cymene whatever by this treatment (although it does by bromine and heat), and that cymene may be obtained from nutmeg hydrocarbons or from oil of turpentine without evolution of sulphur dioxide, if very great care be taken.

Kekulé, also, has recently obtained cymene from oil of turpentine by continued distillation along with iodine; he considers that a diiodide is formed and split up into hydriodic acid and cymene by the heat employed: this is by no means improbable; but it is not impossible that the iodine simply polymerizes the terpene present, leaving the cymene originally present unaltered.

F. *Cymene from Cummin-oil.*—Cummin-oil was distilled, a non-volatile resin of empirical formula $C_{14}H_{17}O$ being left in the retort; the distillate was shaken with sodium bisulphite and the uncombined cymene purified by treatment with sulphuric acid and distillation over sodium.

G. *Cymene from Hesperidene Dibromide.*

H. *Cymene from Nutmeg-terpene Dibromide.*—This cymene, of course, also contained the cymene which preexisted in the hydrocarbon used; the preexisting cymene was about 10–12 per cent, whilst the total cymene obtained was 55 per cent. of the hydrocarbon used.

The following were the physical characteristics of these specimens:—

	Boiling-point (corrected).	Corrected		
		Specific gravity (at about 15°).	Specific refractive energy (line A).	Specific dispersion.
A	173° -177°	0·842	0·5586	0·0374
B	176 -178	0·862	0·5596	0·0404
C	175 -178	0·862	0·5628	0·0424
D	173 -177	0·863	0·5561	0·0401
E	174 -177	0·855	0·5581	0·0393
F	175·5–177·5	0·857	0·5623	0·0414
G	175·5–177·5	0·862	0·5607	0·0414
H	176 -178			

Each of these eight specimens gave analytical numbers agreeing with the formula $C_{10}H_{14}$. On oxidation with dichromate of potassium and sulphuric acid the same result was obtained in each case; viz. pure terephthalic acid was obtained in quantity varying from 30 to 60 per cent. of hydrocarbon used, no isophthalic acid being formed, and acetic acid perfectly free from higher homologues was obtained, the results being verified by analysis of the products.

It is hence inferred that only one kind of cymene exists, and that that boils at very close upon 176°·5, having a specific gravity of 0·860, a specific dispersion of 0·0405, and a refraction-equivalent of 75·0. The production of this cymene from *four* isomeric terpenes, viz. turpentine-oil (Williams, Barbier, Oppenheim), citrene (Oppenheim), hesperidene (Wright), and nutmeg-terpene (Wright), gives rise to many speculations as to the mutual relations of these substances. It may be noticed as regards their formularization in accordance with modern conventions, that Kekulé's formula for benzene permits of the ascription of *three* formulæ only for bodies that are dihydrides of cymene if this hydrocarbon be viewed as a 1·4 benzene derivative, but of *six* if it be considered a 1·2 derivative or a 1·3 derivative. If, therefore, it be assumed, as seems most probable, that cymene belongs to that series to which 1·4 formulæ are ascribed, it must be supposed that at any rate one of these four terpenes is either a 1·2 or a 1·3 derivative. Now, whatever may be the actual nature of the process symbolically indicated by a transference of a group of symbols from one part of a "structural" formula to another, it is pretty evident that it must correspond to the performance of work of some kind, and hence is intimately connected with the subject touched upon above, viz. the relations between "Intrinsic Chemical Energy" and Isomerism. Were it possible to estimate the amounts of heat involved in the reactions

$$C_{10}H_{16}+Br_2=C_{10}H_{16}Br_2$$

$$C_{10}H_{16}Br_2 \quad =2HBr+C_{10}H_{14}$$

in various cases, some light might be thrown on this question; but unfortunately this appears to be impracticable.

With a view to obtaining another variety of cymene for comparison with the above, some experiments were made with citronella-oil, which was found by Gladstone to contain a substance boiling at 199°–205°, and agreeing in composition with the formula $C_{10}H_{16}O$; it was expected that this body would behave like myristicol on treatment with zinc chloride or phosphorus pentachloride. On examining about 600 grams of pure oil of citronella obtained from Messrs. Piesse and Lubin, however, no quantity of this constituent could be isolated; the great majority of the oil is made up of a substance which agrees tolerably accurately with the formula $C_{10}H_{18}O$, and boils at near 210°; the action of heat on this substance, however, alters it, converting it into substances of higher boiling-point, and finally into a resin not volatile at the limits of the mercurial thermometer: this resin appears to be a polymeride of $C_{10}H_{18}O$ *minus* the elements of a portion of water.

The examination of the citronella products is not yet complete, and the account of them is therefore deferred until next year; the following points, however, appear to be made out.

By the action of zinc chloride the body $C_{10}H_{18}O$ splits up partially into water and a hydrocarbon, or mixture of hydrocarbons, boiling between 170° and 180°, and approximating to the formula $C_{10}H_{16}$; so that apparently the action is mainly

$$C_{10}H_{18}O = H_2O + C_{10}H_{16}.$$

A large quantity of a resinous body which approximates to the composition $(C_{10}H_{16})_n$ is simultaneously formed.

By the addition of two equivalents of bromine to the body $C_{10}H_{18}O$ heat is developed; on distillation of the resulting brominated liquid (which does not crystallize on standing) it breaks up into water, hydrobromic acid, and a hydrocarbon which appears to be cymene, formed thus—

$$C_{10}H_{18}O + Br_2 = C_{10}H_{18}Br_2O,$$
$$C_{10}H_{18}Br_2O = H_2O + 2HBr + C_{10}H_{14}.$$

It is proposed to continue these researches in whatever direction may seem most promising for the fulfilment of the object in view, viz. the obtaining of additional knowledge on the subject of isomerism in the terpene series and their derivatives. The strong tendency of most of these substances to polymerize and alter, forming resinous non-volatile masses, renders working on this subject somewhat difficult, large quantities of raw material being requisite in order to obtain sufficient of any given derivative to submit it to careful study. From what has been already done, together with the results obtained by Baeyer, Oppenheim, Kekulé, Barbier, &c., it appears that the constituents of the "Essential Oils" (which are most frequently either terpenes or derivatives from terpenes) are intimately connected with the benzene series of hydrocarbons; it is proposed to study these connexions more minutely wherever practicable.

Appendix.

Further experiments, made since the above Report was written, have confirmed the formula $C_{10}H_{18}O$ as that of the main constituent of the sample of citronella-oil examined; phosphorus sulphide acts on this substance just as zinc chloride, producing a terpene boiling at 160°–165°, and polymerides of higher boiling-point. The cymene obtained by the action of bromine appears

to be identical with that obtained from the eight sources described in the above Report.

The main constituent of oil of wormwood (termed by Gladstone *Absinthol*, and indicated by the formula $C_{10}H_{16}O$), when treated with zinc chloride or phosphorus sulphide, splits up in exactly the same way as its isomerides myristicol and camphor, water and *cymene* being formed, thus,

$$C_{10}H_{16}O = H_2O + C_{10}H_{14};$$

the cymene thus formed is identical with that obtained from the other sources examined. The action of phosphorus sulphide also gives rise to the production of a sulphuretted compound apparently identical with the *thiocymene*, $C_{10}H_{13}.SH$, recently obtained by Flesch from the products of the action of phosphorus sulphide on camphor. Further details are postponed until next year's Report.

From the circumstance that different observers have frequently obtained different results in the examination of certain kinds of essential oils (*e. g.* the different properties and compositions of myristicol and the oxidized constituent of citronella-oil found by Gladstone and by the writer), it would seem that the composition of such oils is subject to variation, probably with the age of the plant, the season, climate, &c.

Report of the Committee, consisting of W. CHANDLER ROBERTS, DR. MILLS, DR. BOYCOTT, *and* A. W. GADESDEN, *appointed for the purpose of inquiring into the Method of making Gold-assays, and of stating the Results thereof. Drawn up by* W. CHANDLER ROBERTS, *Secretary.*

THE attention of the Committee was first directed to a series of experiments instituted with a view to ascertain to what extent the weights of pieces of pure gold would be affected by submitting them to the process of assaying, and consequently how far the results of assay operations are trustworthy.

These results showed* that the maximum error in no case exceeded one hundredth per cent. of the original weight of the assay piece, and consequently that the results obtained by assaying gold represent the composition of the portions of metal under examination to the $\frac{1}{10,000}$ part—a fact which will doubtless appear remarkable to all who are accustomed to the ordinary methods of quantitative analysis.

The Committee are not unmindful that, although it is possible to attain this high degree of accuracy, it is nevertheless well known that a comparison of the assay reports of different assayers as to the composition of the same ingot often discloses discrepancies of $\frac{5}{10,000}$ parts. Thus portions of metal from nineteen gold ingots were assayed by the Mint Assayer†, and were then sent to five assayers, each of whom furnished an independent report.

Two assayers alone agreed as to the value of fifteen of these ingots; in the case of three ingots, three assayers were in accordance, while in one instance all the assay reports differed; and viewing the reports generally, the discrepancies varied from $\frac{2}{10,000}$ to $\frac{10}{10,000}$, or an average deviation of $\frac{6}{10,000}$ parts.

* Appendix I. † Appendix II.

These small variations assume serious proportions when they affect the value of large quantities of bullion; for instance, the value of gold coined at the Mint during the past year was £15,200,000, and a persistent error in the assay reports of only $\frac{1}{10,000}$ part would have been attended with a gain or loss to the Department of no less than £1500.

The Committee hope that their labours will ultimately result in a clear definition of the conditions under which errors arise.

The method of gold-assaying, as practised in the Mint, is given in the Appendix*; and this method, known as the parting assay, has been deliberately adopted by all assayers, with slight variations of manipulation, which have not as yet been minutely examined, as the Committee considered that when widely divergent results are obtained the gold employed by one or other of the assayers as "check pieces" is impure, and that either the amount of impurity has not been ascertained with accuracy, or it altogether escapes detection. It follows, therefore, that the weight of the check "cornets," when compared with the initial weight of the portion of metal operated upon, appears to indicate the presence of an amount of gold which is in excess of the true amount of precious metal present in the alloy.

The Committee obtained specimens of gold from different sources*, and tested them side by side with gold prepared, in accordance with the directions of the Lords Commissioners of Her Majesty's Treasury, by the Chemist of the Mint for use as trial-plate for testing the coinage.

Great care was taken in the preparation of this gold, 80 ounces of which were precipitated from 100 gallons of chloride of gold; and as experiments have already shown that it is very pure, the Committee propose to adopt it as the basis for a new series of comparisons, and, further, to invite assayers to submit samples of the gold used by them in order that they may be tested side by side with this standard plate.

APPENDIX.

No. I.

Experiments to determine the effect produced on the weight of assay pieces of fine gold (each weighing 1000) by submitting them to the process of assay.

Experiment.	Weight of each portion of fine gold = 0·5 grm., or 1000·0 assay units.	Final weight of gold obtained.
I.	1000·0	999·98
II.	1000·0	1000·08
III.	1000·0	1000·06
IV.	1000·0	1000·10
V.	1000·0	1000·04
VI.	1000·0	1000·09
VII.	1000·0	1000 09
VIII.	1000·0	999·92
IX.	1000·0	1000·04
X.	1000·0	1000·05
	Mean.........	1000·045

* Appendix III.

No. II.

Mint Assays.	Bars.	Assayers. A.	B.	C.	D.	E.	Agreements.	Maximum difference in tenths of a Millième.
	No.							
997·4	15.	997·3	997·1	996·9	997·4	997·4	2	·5
997·6	16.	997·8	997·8	997·6	998·5	998	2	·9
997·6	17.	997 8	997·9	997·5	997·2	997·9	2	·7
997·7	18.	997 4	997·5	997 7	997·5	997·6	2	·3
996 7	19.	997	997	997	997·4	997·2	3	·4
996·3	20.	996·3	996·4	996·4	997	996·1	2	·9
997·4	21.	997·6	997·8	997 2	997·8	997·8	3	·6
998·1	22.	998	997 4	997 6	997 4	998	2 2	·6
997·4	23.	997·5	997·5	998	998	997·8	2 2	·5
986·6	24.	987	987 1	987·4	987 4	987·2	2	·4
990 4	25.	989·8	989 1	989·4	989 8	989 3	2	·7
984·8	26.	985	984·8	985 4	985·6	985	2	·8
986 1	27.	986·2	986 3	986 1	986·8	986·3	2	·7
989	28.	989	989·3	989·4	989 8	989 4	2	·8
988 3	29.	988 6	988 5	988 8	989 1	988·7	...	·6
984·9	30.	985 3	985	985·4	985·3	985·1	2	·4
980 2	31.	980 6	980 6	980 8	980·6	981	3	·4
978·1	32.	978·8	978	978 1	978 6	978·1	2	·8
979·2	33.	979 8	979 5	979 9	980	979 5	2	·5
977·9	34.	978 8	977·9	978·9	978 8	978 3	2	1·0
						Average		·6

No. III.

Gold-assaying.

The process of gold-assaying comprises six distinct operations:—

1st process.—The portion of metal to be assayed is adjusted to an exact weight by cutting and filing.

2nd process.—The accurately weighed portions of alloy are added to molten admixtures of lead and silver contained in porous cups or "cupels" of bone ash, which are arranged in rows in a muffle or small oven. The proportions of the latter metals are calculated so as to bear a definite relation to the supposed amount of gold and base metals present in the alloy.

Result.—The lead oxidizes and is absorbed by the porous "cupel," together with the copper and other oxidizable metals, and the silver and gold remain in the form of a button, which may also contain platinum, iridium, or metals possessing similar properties.

3rd process.—The button is reduced by rolling to a thin strip, which is annealed and bent into a loose coil or "cornet."

4th process.—The "cornet" is placed in nitric acid of the specific gravity of 1·25, and the acid is maintained at incipient ebullition for 15 minutes; the coil is then treated in a similar manner with nitric acid of specific gravity 1·4.

Result.—The silver is removed by the action of the acid; and the gold remains in a spongy state.

5th process.—The sponge of gold retains the original form of the coil; but it is necessary to impart a certain degree of coherence to the metal by annealing it at a dull red heat.

It may be observed that a small quantity of silver is invariably retained by the gold. It is necessary therefore to make check assays on pure gold or on standards of known composition, upon which the accuracy of the result will in a great measure depend.

6th process.—This, the concluding process, consists in weighing the gold "cornet." The weights implied bear a decimal relation to the original weight of the assay piece operated upon; and therefore the amount of gold present in the alloy is at once indicated without further calculation.

Table showing the Relative Purity of Samples of Gold prepared by different Methods.

Sample.		
A.	From a dilute solution of chloride of gold by sulphurous acid gas	1000·00
B.	From chloride of gold by oxalic acid	999·98
C.	The trial-plate, prepared by same process as Sample A	999·95
D.	Prepared by α	999·93
E.	Prepared by β	999·80
F.	Prepared by γ	999·70
G.	Prepared by δ	999·60

First Report of the Committee for the Selection and Nomenclature of Dynamical and Electrical Units, the Committee consisting of Sir W. Thomson, Professor G. C. Foster, Professor J. C. Maxwell, Mr. G. J. Stoney, Professor Fleeming Jenkin, Dr. Siemens, Mr. F. J. Bramwell, *and* Professor Everett (Reporter).

We consider that the most urgent portion of the task intrusted to us is that which concerns the selection and nomenclature of units of force and energy; and under this head we are prepared to offer a definite recommendation.

A more extensive and difficult part of our duty is the selection and nomenclature of electrical and magnetic units. Under this head we are prepared with a definite recommendation as regards selection, but with only an interim recommendation as regards nomenclature.

Up to the present time it has been necessary for every person who wishes to specify a magnitude in what is called "absolute" measure, to mention the three fundamental units of mass, length, and time which he has chosen as the basis of his system. This necessity will be obviated if one definite selection of three fundamental units be made once for all, and accepted by the general consent of scientific men. We are strongly of opinion that such a selection ought at once to be made, and to be so made that there will be no subsequent necessity for amending it.

We think that, in the selection of each kind of derived unit, all arbitrary multiplications and divisions by powers of ten, or other factors, must be rigorously avoided, and the whole system of fundamental units of force, work, electrostatic, and electromagnetic elements must be fixed at one common level—that level, namely, which is determined by direct derivation from the three fundamental units once for all selected.

The carrying out of this resolution involves the adoption of some units which are excessively large or excessively small in comparison with the magnitudes which occur in practice; but a remedy for this inconvenience is provided by a method of denoting decimal multiples and submultiples, which has already been extensively adopted, and which we desire to recommend for general use.

On the initial question of the particular units of mass, length, and time to be recommended as the basis of the whole system, a protracted discussion has been carried on, the principal point discussed being the claims of the gramme, the *metre*, and the second, as against the gramme, the *centimetre*, and the second,—the former combination having an advantage as regards the simplicity of the name *metre*, while the latter combination has the advantage of making the unit of mass practically identical with the mass of unit-volume of water—in other words, of making the value of the density of water practically equal to unity. We are now all but unanimous in regarding this latter element of simplicity as the more important of the two; and in support of this view we desire to quote the authority of Sir W. Thomson, who has for a long time insisted very strongly upon the necessity of employing units which conform to this condition.

We accordingly recommend the general adoption of the *Centimetre*, the *Gramme*, and the *Second* as the three fundamental units; and until such time as special names shall be appropriated to the units of electrical and magnetic magnitude hence derived, we recommend that they be distinguished from "absolute" units otherwise derived, by the letters "C. G. S." prefixed, these being the initial letters of the names of the three fundamental units.

Special names, if short and suitable, would, in the opinion of a majority of us, be better than the provisional designations "C. G. S. unit of . . . ." Several lists of names have already been suggested; and attentive consideration will be given to any further suggestions which we may receive from persons interested in electrical nomenclature.

The "ohm," as represented by the original standard coil, is approximately 10^9 C. G. S. units of resistance; the "volt" is approximately 10^8 C. G. S. units of electromotive force; and the "farad" is approximately $\frac{1}{10^9}$ of the C. G. S. unit of capacity.

For the expression of high decimal multiples and submultiples, we recommend the system introduced by Mr. Stoney, a system which has already been extensively employed for electrical purposes. It consists in denoting the exponent of the power of 10, which serves as multiplier, by an appended

cardinal number, if the exponent be positive, and by a prefixed ordinal number if the exponent be negative.

Thus 10^9 grammes constitute a *gramme-nine*; $\frac{1}{10^9}$ of a gramme constitutes a *ninth-gramme*; the approximate length of a quadrant of one of the earth's meridians is a *metre-seven*, or a *centimetre-nine*.

For multiplication or division by a million, the prefixes *mega* * and *micro* may conveniently be employed, according to the present custom of electricians. Thus the *megohm* is a million ohms, and the *microfarad* is the millionth part of a farad. The prefix *mega* is equivalent to the affix *six*. The prefix *micro* is equivalent to the prefix *sixth*.

The prefixes *kilo*, *hecto*, *deca*, *deci*, *centi*, *milli* can also be employed in their usual senses before all new names of units.

As regards the name to be given to the C. G. S. *unit of force*, we recommend that it be a derivative of the Greek δύναμις. The form *dynamy* appears to be the most satisfactory to etymologists. *Dynam* is equally intelligible, but awkward in sound to English ears. The shorter form, *dyne*, though not fashioned according to strict rules of etymology, will probably be generally preferred in this country. Bearing in mind that it is desirable to construct a system with a view to its becoming international, we think that the termination of the word should for the present be left an open question. But we would earnestly request that, whichever form of the word be employed, its meaning be strictly limited to the unit of force of the C. G. S. system—that is to say, *the force which, acting upon a gramme of matter for a second, generates a velocity of a centimetre per second.*

The C. G. S. *unit of work* is the work done by *this force working through a centimetre*; and we propose to denote it by some derivative of the Greek ἔργον. The forms *ergon*, *ergal*, and *erg* have been suggested; but the second of these has been used in a different sense by Clausius. In this case also we propose, for the present, to leave the termination unsettled; and we request that the word *ergon*, or *erg*, be strictly limited to the C. G. S. unit of work, or what is, for purposes of measurement, equivalent to this, the C. G. S. *unit of energy*, energy being measured by the amount of work which it represents.

The C. G. S. *unit of power* is the power of doing work at the rate of *one erg per second*; and the power of an engine, under given conditions of working, can be specified in *ergs per second*.

For rough comparison with the vulgar (and variable) units based on terrestrial gravitation, the following statement will be useful:—

The *weight* of a *gramme*, at any part of the earth's surface, is about 980 *dynes*, or rather less than a *kilodyne*.

The *weight* of a *kilogramme* is rather less than a *megadyne*, being about 980,000 *dynes*.

Conversely, the *dyne* is about 1·02 times the *weight* of a *milligramme* at any part of the earth's surface; and the *megadyne* is about 1·02 times the *weight* of a *kilogramme*.

The *kilogrammetre* is rather less than the *ergon-eight*, being about 98 million *ergs*.

The *gramme-centimetre* is rather less than the *kilerg*, being about 980 *ergs*.

For exact comparison, the value of g (the acceleration of a body falling *in vacuo*) at the station considered must of course be known. In the above comparisons it is taken as 980 C. G. S. units of acceleration.

* Before a vowel, either *meg* or *megal*, as euphony may suggest, may be employed instead of *mega*.

One *horse-power* is about three quarters of an *erg-ten* per second. More nearly, it is 7·46 *erg-nines* per second; and one *force-de-cheval* is 7·36 *erg-nines* per second.

The mechanical equivalent of one *gramme-degree* (Centigrade) of heat is 41·6 megalergs, or 41,600,000 *ergs*.

APPENDIX.

Mr. Stoney has requested the insertion of the following extract from one of his letters, written subsequently to the presentation of the foregoing Report:—

"Would you oblige me very much by putting on record, either in the Report or as a footnote to it, that the centimetre was recommended as the unit of length against my earnest remonstrance, and that I am in no degree responsible for this decision. I would be glad to have the objections I urged against it stated also. They were, 'that it is far too small, and that its multiples and submultiples cannot be briefly designated. From its being too small, it, in conjunction with the gramme and second, lands us in quite out-of-the-way mechanical units—the unit of force which results being but little more than the pressure of a milligramme, and the unit of work being but little more than the hundredthousandth part of a grammetre. This I deem a very serious objection.'

"I still think that these awkward consequences, and the footing which the metre has already gained in science, will prove fatal to the recommendation of the Committee, and that experience will show that the metre must in the end be accepted as the standard unit of length."

Report of the Committee, consisting of Professor PHILLIPS, *LL.D., F.R.S.,* Professor HARKNESS, *F.R.S.,* HENRY WOODWARD, *F.R.S.,* JAMES THOMSON, JOHN BRIGG, *and* L. C. MIALL, *on the Labyrinthodonts of the Coal-measures. Drawn up by* L. C. MIALL, *Secretary to the Committee.*

[PLATES I., II., III.]

THE Committee have to report that some of their number have personally examined all the more important examples of Labyrinthodonts in European collections, including at least one example of every species recorded from the British Isles. They desire to thank many private collectors and officers of public museums for facilities afforded.

The preparation of a memoir on the classification of the Carboniferous species is in progress; meanwhile the Committee offer a preliminary sketch of the structure of the Labyrinthodonts.

The Skull (general).—The general figure of the skull varies greatly in this order. It is usually triangular, with a rounded anterior end, and a concave posterior border, but may be oval, parabolic, pyriform, or hexagonal. In one species of *Archegosaurus* (*A. Decheni*) it is greatly produced, so that the length exceeds twice the breadth. More commonly the greatest breadth is nearly equal to the length. In *Brachyops* the greatest breadth is rather more than the length. The upper and lower surfaces of the cranium are usually crushed flat. Rarely, as in the single skull of *Zygosaurus* and in one example of *Loxomma,* is the original contour preserved.

The following bones have been identified in the skulls of Labyrinthodonts:—

Premaxillaries (one or two).	Supratemporals (two).
Maxillaries (two).	Quadrato-jugals (two).
Nasals (two).	Supraoccipitals (one or two).
Lachrymals (two).	Exoccipitals (two).
Frontals (two).	Parasphenoid.
Prefrontals (two).	Pterygoids (two).
Postfrontals (two).	Palatals (two).
Postorbitals (two).	Vomers (two).
Jugals (two).	Quadrates (two).
Parietals (two).	Mandible (each ramus consisting normally of three pieces, viz. articular, angular, and dentary).
Squamosals (two).	
Epiotics (two).	

There may thus be forty-seven distinct elements present; and this is apparently the number in *Loxomma* (Pl. I.).

In *Trematosaurus* the premaxillaries are united. According to Cope * there is no quadrato-jugal in *Pariostegus*, but the maxillaries have a free termination behind. *Pteroplax* appears, from at least three well-preserved specimens, to have no maxillaries, resembling in this respect the recent Siren; it wants also the postero-lateral ossifications external to the level of the orbits †. In *Batrachiderpeton* the maxillaries are undoubtedly absent, and the premaxillaries have a free posterior termination ‡. All the well-preserved mandibles hitherto examined have consisted of three pieces only in each ramus. Burmeister has described six elements as present in a shattered mandible of *Trematosaurus* §; and Mr. Hancock records a splenial piece in the mandible of *Anthracosaurus* ‖. The jaw upon which this latter determination is founded is fragmentary, and the internal plate in question may prove to be part of the articular bone. At the time of the publication of the 'Paläontologie Würtembergs,' Von Meyer seems to have attributed six mandibular elements to *Mastodonsaurus* (pp. 18, 25); but this is certainly erroneous. Prof. Huxley speaks of a splenial in *Pachygonia* and *Gonioglyptus*.

The general disposition of these bones is similar to that of the Crocodilian skull. The resemblance is closer as regards the bones of the upper surface than with respect to those which compose the palate, and it does not hold good at all of the axial elements of the skull. The occipital and sphenoidal ossifications differ essentially from those of the Crocodile or any other reptile.

The superior surface of the skull is interrupted by five openings, viz. two nasal apertures or external nares, two orbits, and a parietal foramen. The apertures of the ears are situate at the junction of the superior and posterior surfaces, adjacent to the epiotics. There are no lateral-temporal ¶ or supratemporal fossæ, as in Crocodilia, nor any of the spaces unoccupied by bone which, in addition to the nasal apertures and orbits, break up the roof of the cranium in most existing Amphibia. (*Dasyceps* has a "facial fontanelle" **.)

* Trans. American Philosophical Society, vol. xiv. N.S. pt. 1, p. 10 (1870).
† Nat. Hist. Trans. Northumberland and Durham, vol. iv. pt. 1, p. 216 (1871).
‡ Ibid. p. 216.
§ Die Labyrinthodonten aus dem bunten Sandstein, pt. 1, pp. 38–41 (1849).
‖ Nat. Hist. Trans. Northumberland and Durham, vol. iv. pt. 2, p. 388 (1872).
¶ Lateral-temporal fossæ have been supposed to occur in *Zygosaurus*. See p. 235 (footnote).
** See appendix by Prof. Huxley to Howell's "Memoir on the Geology of the Warwick Coal-field," Mem. Geol. Survey, p. 54.

The posterior or occipital surface is more or less vertical. It may present an occipital foramen, a pair of occipital condyles, the apertures of the ears; which are directed backwards, and the large openings of the palato-temporal or pterygoid fossæ. On each side of the occipital bones there may project horizontally backwards the postero-internal or epiotic cornua. The articular surface for the lower jaw forms the external and inferior angle, when it is well preserved. It appears to have been often in great part cartilaginous.

The inferior or palatal surface of the cranium is rarely exposed. A parasphenoid, as in Teleostean and Ganoid fishes and recent Amphibia, extends forwards from the occipital region, and passes into a rostrum or *processus cultriformis* in front. The posterior part of the parasphenoid is usually expanded, and presents lateral wings which are continuous with the pterygo-palatine processes. The palatine foramina, which are oval and usually of large size, are separated from each other by the *processus cultriformis*, or by this and the vomers together. A transverse bridge of bone, consisting of a pterygoid, or of a pterygoid and a palatal, divides the palatine foramen from the palato-temporal fossa. A narrow slip, furnished by the maxilla, and containing a row of teeth, lies along the outer edge of the mouth, and has the elongated palatal on its inner side as far forwards as the posterior nares. There are a pair of vomers, as in recent Amphibia. Like the palatals, they bear teeth. The posterior nares are oval or rounded apertures, varying a good deal in position. In *Trematosaurus* * they lie between the palatal, vomer, and maxilla, towards the fore part of the snout. In *Anthracosaurus* they are placed much further back, though probably bounded by the same bones. The longitudinal distance between the external and posterior nares may be considerable, as in *Labyrinthodon*†, or very short, as in *Dasyceps*‡. The latter genus must have had nearly vertical nasal passages, like recent Batrachia. In no Labyrinthodont is the prolongation backwards of the nasal passages at all comparable to that which obtains in Crocodilia. A pair of cavities lying in or adjacent to the premaxillaries may represent pits for the reception of mandibular tusks, or spaces occupied by membrane. The first explanation was proposed by Burmeister in his remarks on *Trematosaurus*; but Von Meyer observes that the apertures do not in all species of Labyrinthodonta correspond with the position of the large teeth of the mandible. If this supposition be rejected, we must regard the apertures as anterior palatine foramina.

The subcutaneous surface of the cranial bones is ordinarily sculptured. This sculpture may take the form of pits arranged in each bone round the centre of ossification. The pits sometimes pass into grooves towards the margin of the bone, and are then placed radially, all the grooves pointing towards one centre, which does not, however, in the adult necessarily, or indeed usually, occupy the middle point of the bone. The skull of *Loxomma* has a honeycomb surface; and in *Hylonomus*§ the cranial bones are smooth.

Besides these local systems of pits or grooves, a series of more continuous "mucous canals" is seen in some genera, taking the form of semicylindrical grooves which pass from before to behind along the face. These canals vary much as to their extent and prominence. They may be confined to the muzzle, or may be found in the temporal and maxillary regions also. They are usually visible between and in front of the orbits, approaching each other

* Burmeister, 'Die Labyrinthodonten aus dem bunten Sandstein. I. *Trematosaurus* (1849).

† Owen, 'Trans. Geol. Soc.' vol. vi. 2nd series, p. 531 (1842). ‡ Huxley, *loc. cit.* p. 56.

§ Dawson, 'Acadian Geology,' 2nd ed. p. 371 (1868).

in the interorbital space, and receding from each other over the parietal tract. Sometimes they are seen to converge once more towards the anterior or external nares, completing thus the figure of a lyre, which they have been thought to resemble. They become deeper and more defined with age.

In *Trematosaurus*, Burmeister* distinguishes frontal, malar, and maxillary canals ("Stirn-, Backen-, und Mundrand-Furchen"). The frontal canals are first conspicuous between the anterior nasal apertures, running parallel to each other at this point. They pass in diverging curves backwards across the snout, are approximated towards the orbits, immediately behind which they diverge again, and then terminate. The malar canals are somewhat broader. They pass forwards from the aperture of the ear to the centre of the postorbital, curve downwards to near the angle of the mouth, where they touch the maxillary canals, and then take a nearly straight course across the jugal and supratemporal to the posterior margin of the skull. The maxillary canals are faintly marked at their origin near the tip of the snout, but become gradually broader and deeper. They rise a little upon the side of the skull halfway between the nasal apertures and the orbits, but are contiguous to the edge of the mouth throughout the rest of their course. They disappear gradually near the angle of the mouth. The mucous canals of *Mastodonsaurus* are very similar, but the lyra is more dilated and more regularly oval. In *Gonioglyptus*† the facial canals are strongly angulated, curving outwards and forwards from the interorbital space, and then suddenly becoming parallel.

In *Archegosaurus* the mucous canals are visible only in the large skulls. They are distinct along the inner border of the orbit, passing thence forwards upon the prefrontal, and backwards upon the postfrontal and supratemporal. Burmeister's restoration ‡ seems to exhibit the canals too prominently upon the preorbital part of the face.

In *Loxomma* the canals pass in simple curves from the inner borders of the orbits to the posterior external angles of the premaxillaries, and are united in front by a slightly curved canal which runs along the free border of the premaxillaries above the alveolus. A short maxillary canal is present in this genus.

The skulls of Crocodilia agree with those of the Labyrinthodonts in having a pitted sculpture, though in the former order the pits and grooves are not usually radiate. Mucous canals are not found in Crocodilia. Both kinds of sculpture are, in all probability, related to the nutrition of the cutis.

The cranial bones (with the exception of the quadrate and parts of the occipital segment in many Carboniferous Labyrinthodonts) are fully ossified, and this from the time that the animal leaves the shell. As a rule, no interspaces or fontanelles are visible at any age §, though examples of *Archegosaurus* of embryonic size, in which the skull was not more than one twentieth of the length of the adult state, have been examined with reference to this point.

This mode of development of the skull is not confined to Labyrinthodonts. In Crocodilia the same thing is observed. A recently hatched Crocodile presents no cranial interspaces or fontanelles. Not only are the sutures of the Crocodilian skull closed before the end of embryonic life, but the frontals and

* *Trematosaurus*, p. 6.

† Huxley, "Vertebrate Fossils from the Panchet Rocks," Palæontologica Indica, p. 5, t. vi. f. 1 (1865).

‡ *Archegosaurus*, p. 8. t. iv. fig. 1.

§ A membranous interspace, or "facial fontanelle," exists in *Dasyceps*.

parietals, originally paired bones, are respectively united at that early period. This rapid formation of a solid and compactly articulated skull does not preclude the further growth of every separate bone. In both Crocodilia and Labyrinthodonts the skull ultimately becomes many times as large as it was at birth, retaining all the time its accurately closed sutures, and increasing by additions to all the borders of each ossification. The growth of the Crocodilian skull appears to be quite indefinite, ending only with the life of the individual; and the same may have been true of the Labyrinthodont. This mode of enlargement is compatible with great progressive changes in the proportions of the skull. In Crocodilia and Labyrinthodonts alike, the face increases more rapidly than the brain-case; so that the orbits may recede from near the centre to the junction of the posterior and middle thirds of the skull. This is the case, for example, with *Archegosaurus Decheni*.

All these peculiarities of the skull—the early ossification and junction by suture of the cranial bones, their indefinite or, at least, protracted growth, the generally persistent sutures which are implied thereby, the ever-increasing ratio of the entire skull to the chamber in which the brain is lodged, and, lastly, the pitted sculpture of the subcutaneous surfaces—are interesting points of physiological resemblance between the Labyrinthodonts and Crocodilia; but they are too directly associated with mode of life and external conditions to support any argument as to zoological affinity.

The orbits vary much as to size, position, and form. In *Loxomma* they are ·36 of the length of the skull along the middle line; in *Dasyceps* not more than ·1. In *Metopias* they lie in the anterior half of the skull; in *Mastodonsaurus* they are nearly central; in *Capitosaurus* they lie in the posterior half. As to form, they may be round, oval, elliptical, or irregular. In *Pteroplax* and *Batrachiderpeton* the outer bony wall (at least) of the orbit seems to be deficient.

The interorbital space and the external nasal apertures are equally variable.

The Occipital Segment.—It is to be regretted that the occipital region of the Labyrinthodonts, especially of the Carboniferous genera, is so imperfectly known. No part of the skull would yield characters of greater zoological significance were its structure fully revealed. In most of the Carboniferous examples examined nothing is shown of the occipital segment, except one or two supraoccipital plates. The deficiency of occipital condyles in *Archegosaurus*, of which many singularly perfect specimens have occurred, seems to show that, like the vertebral centra of that genus, they were never ossified, but remained cartilaginous throughout life. *Loxomma*, on the contrary, which has well-ossified centra, has also ossified condyles; they are small, very convex, and closely approximated. In the Triassic Labyrinthodonts the occipital region was fully ossified; and these are our best guides to the structure of the occipital segment in the whole order. Even in the Triassic species the basioccipital is concealed by a parasphenoid, and the form of the occiput, with its numerous cavities and processes, is not favourable to the complete preservation of details.

The boundaries of the component parts of the occipital segment have in no case been traced. It is probable that in the Mastodonsauria (e. g. *Trematosaurus*) a pair of exoccipitals surrounded the foramen magnum*, and supported the occipital condyles, that a cartilaginous supraoccipital, ultimately replaced by a pair of membrane-bones, surmounted the segment, and that in the basioccipital tract the cartilaginous primordial skull was never ossified, but was underlain and finally absorbed by the parasphenoid plate. In

* Burmeister, *Trematosaurus*, p. 24.

Archegosaurus the elements of the occipital segment proper may have been persistently cartilaginous, except so far as they were encroached upon by the supraoccipital and parasphenoid ossifications. The condyles were most probably entirely cartilaginous. Professor Owen* supposes that "the head was connected by ligament, as in Protopteri, to the vertebral column of the trunk, and chiefly by the basioccipital part."

The existence of two lateral occipital condyles in this order is a feature of great morphological importance and zoological value. If, as Von Meyer and many other writers have supposed, the Labyrinthodonts are true Reptilia, they constitute the one exception to the rule that in each of the four higher classes of Vertebrata the number of occipital condyles is constant.

The Parasphenoid (sphenoideum of Von Meyer† and Burmeister‡).—In *Trematosaurus* a large undivided bone underlies the base of the cranium, giving off on either side a postero-lateral process which joins the suspensorial peduncle. In front it passes into a rostrum or *processus cultriformis*, which separates the palatine foramina, and articulates in front with the vomers. Between the postero-lateral and the cultriform processes there is on each side a broad outstanding extension of the parasphenoid, which joins the pterygoid, and, together with that bone, separates the palatine foramen from the palato-temporal fossa§. Burmeister describes lateral ascending processes of the bone as passing upwards to join the margins of the parietals on the under-side of the cranial roof and extending forwards to about the level of the parietal foramen ||. The parasphenoid of *Mastodonsaurus* has in general the same form and relations.

In *Archegosaurus* a similar bone is found, but so displaced that its connexions cannot be accurately made out. It is of spatulate form—the posterior end being dilated and of rounded triangular or polygonal outline, while the anterior end is extended into a long slender *processus cultriformis*. The expanded end is often displaced backwards so as to project beyond the base of the skull. The connexions of this bone with the pterygoid are shown in one of the examples figured by Von Meyer ¶. Its position with respect to the palatine foramen and the palato-temporal fossa appears to have been much the same as in *Trematosaurus*; but there is no trace of any postero-lateral process given off to join the quadrate. That bone has not, indeed, been identified in any specimen of *Archegosaurus*; nor is the mandibular articulation known in this genus**. The fore part of the parasphenoid of *Anthracosaurus* is known ††. It agrees in all essential points with that of *Archegosaurus*. Prof. Owen has figured a detached parasphenoid of *Dendrerpeton* associated with other bones; but no mention is made of it in the text‡‡.

In *Loxomma* the upper surface of the parasphenoid has been examined. About an inch in advance of the spheno-occipital suture are two broken processes $\frac{1}{3}$ of an inch apart, which are directed towards the parietal bones. Again in advance is a strong median ridge, extending as far as the anterior third of the palatine foramen, which may have supported an interorbital septum.

There is no ground for doubting that this element of the Labyrinthodont

* Comp. Anat. of Vertebrates, vol. i. p. 85.

† Reptilien aus der Steinkohlenformation, p. 19.

‡ *Trematosaurus*, p. 29.

§ Burmeister, *Trematosaurus*, § 14.

|| *Loc. cit.* p. 30.

¶ Reptilien aus der Steinkohlenformation, t. v. fig. 7.

** The parasphenoid of *Archegosaurus* is described by Von Meyer, 'Reptilien' &c., p. 19.

†† Huxley, "Description of *Anthracosaurus Russelli*," Quart. Journ. Geol. Soc. vol. xix. p. 56 (1863).

‡‡ Quart. Journ. Geol. Soc. vol. ix. p. 58 (1853); see also pl. ii. fig. 2.

skull is homologous with the parasphenoid of recent Teleostean Fishes, Ganoids, and Amphibia*.

The Pterygoid.—A pterygoid element may be recognized in a bone which is found to lie contiguous to the parasphenoid of *Archegosaurus* in several examples†. The two bones are shown but little disturbed in plate v. fig. 7 of Von Meyer's great work. In *Trematosaurus* the boundaries of the bone have not been traced, though its position is not doubtful‡. The pterygoids of *Mastodonsaurus*, *Metopias*, and others, are known in the same way.

In *Archegosaurus*, as probably in all Labyrinthodonts, the Amphibian plan of structure prevails in the pterygoid region. There are two pterygoids; and these are nowhere in contact, but are separated by the parasphenoid. Each pterygoid has a broad surface which divides the palatine foramen in front from the palato-temporal fossa behind, passing transversely, but somewhat obliquely, from the parasphenoid internally to the palatal on the outer side. In addition to this transverse plate there is in *Archegosaurus*, *Batrachiderpeton*, and *Loxomma*, at least, a long slender process, which is continued forwards along the outer margin of the palatine foramen; its anterior termination is unknown.

The Palatal.—The lower surface of the palatal presents the form of a long and narrow slip interposed between the maxilla and the produced anterior part of the pterygoid. Its boundaries have not been accurately traced in any Labyrinthodont; but it appears to reach the vomer in front, and to form part of the boundary of the posterior nasal aperture, while behind it may help to bound the palato-temporal fossa. The palatal usually bears a series of teeth, which increase in size from the ordinary size of maxillary teeth behind to large tusks in front§.

In recent Batrachia the palatal is transverse, dividing the palatine from the posterior nasal foramina; but in Gymnophiona it closes the posterior nares behind, and then extends backwards along the inner side of the maxilla, as in Labyrinthodonts ‖.

The Vomer.—In Labyrinthodonts (as in Crocodilia, Lacertilia, Ophidia, and all recent Amphibia, excepting a few Batrachia¶), the vomer is double. It is usually bounded by the premaxillaries in front, by the maxilla, posterior nasal aperture, and end of the palatal externally, and along the middle line by its fellow of the opposite side. The posterior margin appears to be usually connected with the *processus cultriformis* mesially, and with the palatal on the outer side; while between these points it forms part of the anterior boundary of the palatal foramen. The vomer in Labyrinthodonts is of great proportionate breadth, forming an unusually large part of the bony palate.

A row of vomerine teeth of varying number, some of which are of large size, is disposed longitudinally along the bone in *Trematosaurus*, *Archego-*

* "One thing [in the skull of the Bullfrog, *Rana pipiens*, L.] appears to be quite unique, although it will perhaps turn up in some other type and, perchance, in the extinct 'Labyrinthodont.' This is the presence of an anterior 'parasphenoid,' the fore part of the 'rostrum' being separately ossified."—W. K. Parker "On the Structure and Development of the Skull of the Common Frog," Phil. Trans. vol. clxi. pt. i. p. 193 (1871). This anticipation still waits for fulfilment.

† Von Meyer, 'Reptilien' &c., t. ii. fig. 4, t. v. f. 1, t. vi. f. 7, 8. ‡ Burmeister.

§ The fragment (of *Labyrinthodon*?) figured by Professor Owen (Trans. Geol. Soc. vol. vi. 2 ser. t. xliii. fig. 4) appears to include a portion of the palatal; and there are traces upon it of a row of palatal teeth.

‖ Huxley, 'Anatomy of Vertebrated Animals,' p. 179; Dugès, 'Recherches sur l'ost. et la myol. des Batraciens,' t. xiv. fig. 93.

¶ *Pipa*, *Dactylethra*, *Pelobates*.

saurus, and *Anthracosaurus*. In *Labyrinthodon* this longitudinal row terminates in front with a large tusk, which is at the same time the outermost of a short transverse series*.

In the remarkable genus *Batrachiderpeton*† a very different type of palatal structure is presented. Here the vomers form a pair of large, somewhat triangular plates, which support the premaxillaries in front, and pass to the pterygoids on either side behind. A large central tract of the vomerine surface is thickly covered with minute conical teeth, while the outer margin of what is apparently the same bone bears a series of ten or more stronger compressed teeth‡. The structure here described is most nearly paralleled by the Perennibranchiate Amphibia and by certain fishes, the Carboniferous *Megalichthys* among the rest.

The Premaxillary.—The premaxillary is usually double in Labyrinthodonts, but single in *Trematosaurus*§. Its proportions vary greatly according to age and species.

On the superior surface of the skull the premaxillary articulates with the nasal and maxillary of the same side, and bounds in part the external nasal aperture. On the palatal surface it is supported behind by the vomer and ordinarily by the maxillary also. The row of maxillary teeth is continued along the premaxillary border, in most cases without interruption or marked difference in size. There may be eleven or more premaxillary teeth on each side; the number is not constant beyond the limits of the species.

Elliptical cavities have been observed upon the under surface of the premaxillary; and these have been compared to the dental pits of Alligator by Burmeister, who supposes that they received the large mandibular teeth ||. This view harmonizes well with the structure of *Trematosaurus*, in which there are large tusks internal to the serial mandibular teeth. In *Archegosaurus*, however, there are no tusks in the mandible, yet the cavities in the palatal plate of the præmaxilla are plainly visible. It is possible that these apertures, as well as the similar one in *Anthracosaurus*, may have been vacuities occupied in the living animal by membrane¶.

The premaxillary of *Batrachiderpeton* appears to differ essentially from the bone as it exists in other Labyrinthodonts. It is produced outwards for a short distance beyond the end of the series of teeth, and appears to have terminated in a free point unconnected with a maxilla, as in *Menobranchus*, *Siren*, and *Proteus*.

The Maxilla.—The maxilla in Labyrinthodonts takes the form of a long narrow slip of bone, comprising nearly all the marginal alveoli of the teeth

* Owen, 'Trans. Geol. Soc.' vol. vi. part 2.

† Hancock and Atthey, 'Nat. Hist. Trans. Northumberland and Durham,' vol. iv. p. 208.

‡ This outer slip, reaching to the pterygoid, is possibly a palatal.

§ Burmeister, *loc. cit.* p. 8. "Two premaxillary bones are usually ascribed to the Batrachia; but in many Salamanders they are confluent. Thus, while they are double in *Salamandra*, they are single in *Hemisalamandra*, *Triton*, and *Diemyctylus*. In Amblystomidæ they are double. Among Plethodontidæ they vary. Of Plethodontine genera, *Batrachoseps* and *Stereochila* have them single and *Plethodon* double. Of Spelerpine forms, *Manculus*, *Œdipus*, and *Spelerpes* have but one, and *Geotriton* and *Gyrinophilus* have two premaxillaries. *Desmognathus* and *Amphiuma* have single premaxillaries."—Prof. E. D. Cope, 'Extinct Batrachia, Reptilia, and Aves of North America,' p. 4 (footnote).

|| *Loc. cit.* p. 9. See also Prof. Huxley, 'Anat. of Vert. Animals,' p. 183. "In many of the Labyrinthodonts, again, two of the anterior mandibular teeth take on the form of long tusks, which are received into fossæ, or foramina, of the upper jaw, as in most existing Crocodilia."

¶ In the description of *Anthracosaurus*, Prof. Huxley refers to this cavity as the anterior palatine foramen.

and but little else. It usually extends on either side from the premaxillary to the angle of the mouth, and is in contact with the quadrato-jugal behind. In front, and upon the upper surface of the skull, the maxilla may be somewhat expanded so as to occupy an obtuse angle bounded by the nasal and lachrymal. It generally adjoins the external nasal aperture for a greater or less distance; and its internal facial border is successively contiguous to the nasal, lachrymal, and jugal. Upon the inferior or palatal surface it may reach forwards to the posterior nasal foramen, or be excluded therefrom by the junction of the palatal and vomer. No palatine plate of appreciable breadth is developed; and the maxillæ of opposite sides are nowhere in contact.

Batrachiderpeton and *Pteroplax* have no maxillæ; and *Pariostegus* may have had imperfect maxillæ ending behind in a free point, as in *Salamandra* &c.

The maxillary teeth are usually of small size, and form a regular series, diminishing slightly towards the angle of the mouth. The number in *Archegosaurus* is upwards of thirty; and the gaps represent about as many more. In *Baphetes* and *Labyrinthodon* there are anterior maxillary tusks, while in *Anthracosaurus* both the premaxillary and two or more of the anterior maxillary teeth are of unusual size and strength, almost equalling the vomerine and palatine tusks.

The Nasal.—The nasal bones are double in this order. They bound the external nasal apertures behind, and extend backwards to join the frontals. In front, where they are contiguous to the maxilla or are interposed between the maxilla and the premaxillary, they are broadest, while they gradually contract backwards in proportion to the increasing breadth of the lachrymal.

Like all the bones of the face, not only in Labyrinthodonts but in Vertebrata generally, the nasals become longer and longer relatively to the brain-case as age advances. This is notably the case with long-snouted animals, such as the Crocodilia, and is most apparent in those species of Labyrinthodonts which have elongated skulls (e. g. *Archegosaurus Decheni*). The facial bones of Labyrinthodonts, and particularly the nasals, are as a rule unsymmetrical and variable in form. This is another peculiarity of much-produced skulls; it is exemplified by Ichthyosauria and by Crocodilia, especially old individuals of *Crocodilus intermedius* and *Rhynchosuchus Schlegelii*.

The Lachrymal.—When present, the lachrymal lies anterior to the jugal; it is bounded by the maxilla on the outer side, and by the nasal and prefrontal internally. In *Trematosaurus* Burmeister represents it as reaching the orbit; but in reality it is excluded therefrom by the junction of the prefrontal and jugal, as in most other Labyrinthodonts.

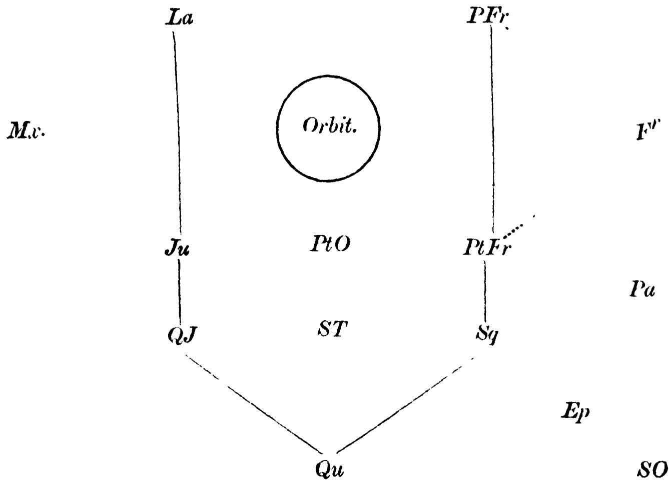
The Frontal, Prefrontal, and Postfrontal.—Three sets of frontal ossifications are normally present, viz. a pair of frontals proper, which lie between the nasals and the parietals in the median or coronal series, and on each side of the head a prefrontal and a postfrontal, which bound respectively the anterior and posterior part of the inner margins of the orbits. The prefrontal and postfrontal generally unite to exclude the frontal proper from the orbit. Externally the prefrontal is, as usual, adjacent to the lachrymal when that bone is present.

The frontals increase more rapidly in length than in breadth as age advances; but the relative change is not so marked as in the case of the nasals. It is most apparent in those species which have, when adult, a much-produced snout. The frontals are always more or less unsymmetrical.

The following diagram, intended to illustrate the general disposition of the

bony plates which roof in the cranium of the Labyrinthodonts, is also applicable in great part to the lower Vertebrates generally. The Crocodilia and the Ganoid fishes agree well with the typical arrangement; but in the latter order other ossifications are intercalated, especially around the orbit. In Crocodilia the postorbital and supratemporal are wanting, the lateral temporal fossa occupying their place, and the epiotic is not externally visible. The postorbitals and supratemporals are not found in any existing Amphibian.

Labyrinthodont Type.



The Parietal.—In all Labyrinthodonts the parietals are paired bones, occupying the normal position between the supraoccipitals and the frontals. The most striking peculiarity which they present is perhaps the parietal foramen, an oval or circular cavity of small size, lying in the interparietal suture. A parietal foramen is known to exist in all the genera in which the parietal bones are sufficiently well preserved to determine the point. As the parietals lengthen with age, the foramen is placed further and further back in the interparietal suture. This is well exemplified by *Archegosaurus Decheni*, a species with a much elongated skull, of which an extensive suite of specimens, differing greatly in age, can be compared. It is relatively large in *Zygosaurus*, and very small in *Mastodonsaurus*.

A parietal foramen is unknown in recent Amphibia*. It is present in Ichthyosauria, Plesiosauria, and many Lacertilia.

In *Batrachiderpeton* the parietal, occipital, and some other adjacent bones are defined by strong raised lines. In this genus the parietals extend unusually far forwards.

The underside of the coronal bones is sometimes smooth (*Mastodonsaurus*); it may present ridges which pass in pairs forwards and backwards from near the parietal foramen. The anterior pair run nearly parallel; but the posterior pair generally diverge rapidly. This aspect of the coronal bones as revealed in a slab of coal-shale, has often a most deceptive resemblance to the parasphenoid of *Ctenodus*. The ridges probably indicate the lines of attachment

* The so-called "fronto-parietal fontanelle" of many recent Batrachia is not to be confounded with the parietal foramen.

of vertical plates connecting the roof and floor of the skull. That these plates were in the Carboniferous Labyrinthodonts usually cartilaginous, is shown by the complete flattening together of the two faces of bone in nearly all the examples which have occurred *.

The Jugal.—When present, the jugal intervenes between the maxilla and the quadrato-jugal. Its relation to the outer side of the orbit is very constant. The jugal is deficient in *Pteroplax* and *Batrachiderpeton*, and probably in *Pariostegus*.

The Supratemporal and Postorbital.—The presence of supratemporal and postorbital bones is one of the distinctive features of the Labyrinthodont skull †. In the recent Gymnophiona the lateral temporal fossæ do not exist; and the Labyrinthodonts are the only Amphibia, recent or fossil, in which the fossæ are closed by special ossifications. The supratemporal and postorbital are not uniformly present in this order.

The "supratemporal foramen," described by Prof. Huxley as occurring in *Anthracosaurus*, appears to be a small perforation in the supratemporal bone. It has no analogy with the supratemporal foramen or fossa of the Crocodilia. *Rhinosaurus* ‡ has a small round foramen at about the same place.

The Squamosal.—The relation of the squamosal to the external auditory meatus renders it highly probable that the internal ear underlies this bone.

A squamosal occurs in all the genera of Labyrinthodonts which are accurately known, except in *Pteroplax*.

The Epiotic.—The pair of membrane-bones named "epiotic" by Prof. Huxley are adjacent to the aperture of the ear and to the supraoccipital plates. They are often pointed behind, like the corresponding ossifications of some Teleostean and Ganoid fishes. Epiotic horns are present in *Loxomma*, *Urocordylus* §, *Pteroplax*, *Batrachiderpeton*, and *Keraterpeton*. In the last-mentioned genus they form great "postero-internal cornua," constituting "about two sevenths of the extreme length of the skull, and are pointed and curved, so as to be slightly convex outwards; their surfaces are rounded from side to side, and longitudinally striated" ‖.

The aperture of the ear is adjacent to the epiotic, and usually indents the occipital or posterior border of the skull.

The Quadrato-jugal.—The quadrato-jugal is to be looked for at the postero-external angle of the skull. In front it articulates with the jugal, and may touch the maxilla. The degree of backward extension of the quadrato-jugal varies greatly, according to the species and, in *Archegosaurus*, according to the age of the individual.

The outer surface is strongly marked with radiating sculpture. Little is known of the under surface; it was probably applied to the mandibular sus-

* Small skulls are sometimes preserved which are nearly free from distortion; and Mr. George Maw has a large skull of *Loxomma* which exhibits the original convexity of the upper surface.

† It has been stated (Eichwald, 'Bulletin de la Société des Naturalistes de Moscou,' tom. xxi. 1848) that *Zygosaurus* has lateral temporal fossæ; but neither the description (p. 167) nor the plates (2, 3) render it quite clear what the structure of this part of the skull really is. The original surface of the bones has been removed by fracture. It seems probable that a broad groove for muscular attachment existed on each side of the parietal tract. There is a trace of the same structure in *Loxomma*. No postorbital aperture, like that of the Crocodilia, is shown; and the temporal region may have been composed of the ossifications usual in Labyrinthodonts.

‡ Fischer de Waldheim, 'Bulletin de la Société des Naturalistes de Moscou,' tom. xx. pt. 1 (1847), p. 364, t. v.

§ Hancock and Atthey, 'Nat. Hist. Trans. Northumberland and Durham,' vol. iii. p. 310.

‖ Huxley, 'Collection of Fossil Vertebrata from Jarrow Colliery, Kilkenny,' p. 5 (1867).

pensorium in great part, but may have furnished points of origin to some of the mandibular muscles.

The relations of the quadrate and quadrato-jugal have not been determined accurately; but there is little chance of error in supposing that the quadrato-jugal represents a membrane-bone investing the mandibular suspensorium, of which the quadrate, when present, constitutes the ossified part. In some cases at least (*Mastodonsaurus*, *Archegosaurus*, *Trematosaurus*) the quadrato-jugal furnishes the outermost part of the articular surface for the mandible.

The Quadrate.—The quadrate of the Labyrinthodonts is as yet very imperfectly known. In *Trematosaurus*, which has yielded the best materials for examination, it is described by Burmeister* as generally similar to the quadrate of the Crocodile, and as contributing the two inner of three rounded depending ridges for the articulation of the mandible, the quadrato-jugal supplying the outermost. No other important details have been distinctly made out.

In *Micropholis* "the articular end, $\frac{3}{16}$ of an inch broad, and flattened from above downwards, exhibits a condyloid surface, which is divided by a groove into a stronger internal and a less prominent external portion. In front of the condyles the quadratum is very thin, but it rapidly expands so as to cover all that remains of the flat lateral face of the suspensorium, and extends forward to about midway between the articular condyle for the mandible and the posterior margin of the orbit. At this point the bony matter disappears "†.

The suspensorium has a downward and backward direction, as in the adult Batrachia. It probably remained more or less cartilaginous in many of the Carboniferous species, as in most recent Amphibia.

The Mandible.—The rami of the mandible are long and straight, of considerable vertical extent near the condyle, and gradually tapering forwards. The upper and lower edges are nearly straight; but in some genera there is a low coronoid process, which rises as an elongated triangle from the upper border, sloping very gradually in front, but rather more rapidly behind.

Each ramus is made up of three elements ‡; (1) a dentary bone, which receives the teeth, and, in some cases, constitutes the upper half of the ramus throughout the greater part of its length; (2) an angular piece, which forms the slightly marked angle of the mandible, and is continued forwards along the lower border, both on the inner and outer side, to near the symphysis, supporting the dentary bone by a groove upon its upper edge. The angular bone is usually ornamented with a strong sculpture, radiating from the angle itself. The articular element (3) comprises the condyle and the upper part of the posterior end of the ramus. Its structure, as revealed by a fine example of the mandible of *Anthracosaurus*, is thus described by Messrs. Hancock and Atthey:—"The articular piece stands well up; the neck is short and stout; the process bearing the glenoid surface is massive, and is transversely elongated, measuring two inches and a quarter long, and an inch wide; the glenoid cavity is deep, and takes a slight sigmoid curve; behind at the outer margin there has been a stout projecting process; and in front towards the inner margin there has been a similar projection of the lip of the articular cavity. It would therefore seem evident that the attachment of the mandible to the tympanic trochlea must have been very firm, rendering the movements of the jaw secure and precise" §. The glenoid cavity of *Loxomma* is described by the same authors as "transversely elongated, deep, and considerably elevated" ‖. It has no postarticular process.

* *Trematosaurus*, pp. 28, 29. † Huxley, 'Quart. Journ. Geol. Soc.' vol. xv. p. 650 (1859).
‡ See p. 226.
§ Nat. Hist. Trans. Northumberland and Durham, vol. iv. p. 389. ‖ Ibid. p. 392.

The mandible of *Mastodonsaurus* has a strong inwardly projecting process, which supports an extension of the glenoid cavity, and a well-developed post-articular process of Crocodilian form and proportions.

These differences might serve to arrange the Labyrinthodonts into two or more groups. In *Mastodonsaurus*, *Anthracosaurus*, *Trematosaurus*, &c. the postarticular process is strong, and projects far backwards. In *Archegosaurus* the process is short and comparatively weak; it is wanting in *Loxomma*.

Mere size will not explain these variations of structure. There is no extraordinary difference of size of cranium among the genera mentioned; and *Loxomma*, which alone wants the postarticular process, is neither the largest nor the smallest. But the structural differences are not improbably due to peculiarities of mode of life. The genera which have the ramus of the mandible produced beyond the glenoid cavity have strong conical teeth, very unequal in size, the largest being set at definite intervals. *Loxomma*, on the contrary, has flattened teeth with two cutting-edges; and the inequality of size which they present is apparently due to irregular replacement. The first group may have had the habits of many Crocodiles, feeding chiefly on dead bodies or terrestrial animals, and consequently requiring strength in mastication rather than special rapidity in opening and closing the jaws. *Loxomma*, on the contrary, may have been a sort of Gavial among the Labyrinthodonts, a fish-eater, whose supply of food depended upon dexterity in snapping up small, quick-moving objects, gaining therefore by a structure of jaw which gives velocity at the expense of force.

The dentary bone supports a row of teeth—and in *Labyrinthodon* a short inner series also, consisting of one, two, or three large tusks which are confined to the symphysial end. This is also apparently the case with *Trematosaurus*, and may be true of other examples, in which the mandible is distorted by lateral compression so as to show tusks apparently in series with smaller teeth. *Dendrerpeton acadianum* is represented as having in the lower jaw "a uniform series of conical teeth, not perceptibly enlarged toward the front, and an inner series of larger and plicated teeth, as in the upper jaw" *.

A large oval aperture has been observed upon the inner side of the lower jaw, a little posterior to the middle of the ramus. It is bounded by the articular bone above, and by the angular bone below. Such an internal mandibular foramen exists in *Mastodonsaurus*, *Trematosaurus*, *Pachygonia*, *Gonioglyptus*, and in undescribed specimens from the Keuper of Warwick. No trace of an external mandibular foramen has been discovered. In Crocodilia both are present.

The mandibular symphysis was incomplete, and the rami were united by ligament or fibro-cartilage, if we may judge from their constant separation in a fossil state. In *Pteroplax* the opposed symphysial ends are expanded by an inwardly directed process from the inferior border of each ramus†.

A mucous canal has been observed to run along the lower margin of the outer surface of the rami in *Pteroplax*, *Loxomma*, and others. A descending canal is strongly marked upon the external surface of the articular and angular bones of some Triassic specimens. The sculpture, commonly present upon the angular bone, may cover the entire subcutaneous surface, as in *Loxomma*.

The outer surface of the posterior end of the mandible is overlapped by the quadrato-jugal, and in some cases by the maxilla also. In *Rhinosaurus* the quadrato-jugal descends for a considerable distance over the mandible, as far as the upper border of the angular bone.

* Dawson, 'Acadian Geology,' 2nd ed. p. 365.

† Hancock and Atthey, 'Nat. Hist. Trans. Northumberland and Durham,' vol. iii. p. 70.

Sclerotic Orbital Ring.—In *Archegosaurus Decheni** and *A. latirostris*†, a series of ossicles, which undoubtedly constituted a bony sclerotic ring, has been found. As many as twenty-three ossicles have been observed in one specimen; but, owing to their scattered position and the perishable nature of the contiguous parts, no example shows the series in its true position. The annular arrangement is distinctly visible in one specimen. The individual ossicles are of nearly quadrilateral form ‡.

Teeth.—It appears from the observations of Von Meyer that the tooth of a Labyrinthodont (*Archegosaurus*) consists at first of a minute hollow cone of enamel armed with two vertical diametrically opposite ridges. This, the true crown of the tooth, retains its original structure and size until it disappears by abrasion or fracture §. It does not, however, remain in its original position, sessile upon the alveolar surface, but is gradually elevated upon a conical base. This base, which is often the only part of the tooth preserved, has the general form of a hollow cone of dentine, coated thinly with enamel, and enclosing a pulp-cavity. The dentinal wall in a well-characterized Labyrinthodont becomes folded longitudinally; and some or nearly all of the folds may be again plaited. In a much convoluted tooth the folds are very compact, and leave only linear spaces between them. In this way the thickness of the dentinal wall is greatly increased, and the central cavity much encroached upon.

In *Labyrinthodon*, Prof. Owen describes a layer of cement as penetrating such of the interspaces between the dentinal folds as communicate with the exterior ‖. This structure is certainly wanting in the Carboniferous Labyrinthodonts, where neither enamel nor cement is present between the folds of dentine. A cross section of such a tooth as has been described exhibits a set of sinuous and, it may be, branched interspaces communicating with the exterior, and corresponding series (separated from the other by the dentinal wall) of sinuous processes of the pulp-cavity.

In some of the Carboniferous species there are no secondary dentinal folds; and it would appear from the descriptions that in some of the "Microsauria" of Dr. Dawson the dentine is not folded at all. Externally the tooth is grooved, and sometimes ridged also. It is frequently compressed in the direction of the axis of the jaw, so as to present an oval or elliptical section. Vertical edges (anterior and posterior) extending downwards upon the basal portion are found in *Loxomma*. In *Pteroplax* they are confined to the apex, but are larger than usual. As a rule they are minute and not persistent.

The teeth were attached to shallow depressions, which take the form of the base and are often marked by radiating ridges corresponding with the dentinal folds. The mandibular alveolus is generally bordered by an external ridge, which may be as much as a quarter of an inch high.

There is always a premaxillary series, and, except where the maxilla is wanting, a maxillary series also. The maxillary teeth may form an uninterrupted row; or large tusks and depressions may occur at intervals. The vomer and palatal are always dentigerous, giving attachment to an inner longitudinal series, parallel with the outer or maxillary series. In *Batra-*

* Goldfuss, Beiträge, p. 7, t. 3. figs. 1, 2; Von Meyer, 'Reptilien' &c., p. 21, t. vi.
† Ibid. p. 125.
‡ A sclerotic ring is present in Lacertilia, Chelonia, Ichthyosauria, Pterosauria, and Birds, absent in all existing Fishes and Amphibia, Plesiosauria, Crocodilia, and Ophidia.
§ In *Loxomma* the crown of the tooth is of great size, and extends far down upon the base.
‖ Trans. Geol. Soc. vol. vi. 2nd series, p. 507, and 'Odontography,' pp. 201, 203. There is no mention of inflection of the enamel, which, it is stated, "ceases at the base of the crown."

chiderpeton the vomerine plates are armed with clustered teeth, resembling the aggregated teeth of *Siren* and *Siredon*. The mandible bears a row of teeth, which may be continuous, or interrupted by large tusks and depressions. A pair of tusks is frequently found near the anterior end of the rami. In *Labyrinthodon*, *Trematosaurus*, and some other genera a short inner series of large teeth is found near the symphysial end of the mandible. Among recent Amphibia a double row of mandibular teeth occurs in *Epicrium* and *Siredon*: it is present in many fishes.

Most commonly a number of teeth are represented only by gaps, or scars upon the alveolar border; the vacant places frequently alternate with the standing teeth, rendering it probable that about half the teeth were normally efficient at the same time, and that they were replaced alternately. The substitution of the palatal teeth was less regular: new teeth appear to have been usually developed upon vacant spaces; but in some instances the successional tooth appears in front, behind, or to the inner side of its predecessor.

Vertebral Column.—The following general features of the vertebral column of Labyrinthodonts may be noted:—

a. The number of vertebræ is large.

b. There are at least two kinds of vertebræ—thoracic and caudal.

c. The centra are biconcave.

d. A superior arch and spine are present in all the vertebræ which are accurately known.

e. Inferior arches are present in the caudal region.

f. Where zygapophyses are present, the anterior look more or less inwards and generally upwards also.

g. The spinal foramen is much contracted.

The chief variations which occur in the corresponding vertebræ of different species are these:—

The centra vary greatly with respect to their degree of ossification. In *Archegosaurus*, for example, the notochord is persistent, and the only osseous parts of the vertebræ are the superior arches, superior spinous processes, transverse processes (proceeding from the laminæ of the superior arches), inferior arches, inferior spinous processes, and lateral wedge-bones ("seitliche Keile" of Von Meyer = "interneural and interhæmal pieces"?). It has been suggested by Professor Huxley * that the inferior arches and lateral wedge-bones may represent osseous rings, like those which remain of the centra of *Megalichthys*, and that "they have broken up into the separate pieces described by Von Meyer in the process of fossilization." In Mastodonsauria, on the contrary, and most of the undoubted Carboniferous Labyrinthodonts, the centra are well ossified. In *Loxomma* and *Anthracosaurus* a small notochordal foramen is apparently persistent. A neuro-central suture appears to have been permanently present in some, if not in all.

The centra of the Carboniferous species are usually discoidal, the antero-posterior length being small; but the vertebræ of *Ophiderpeton* and *Lepterpeton*, as well as those of *Labyrinthodon* † and some of the Microsauria of Dawson have hourglass-shaped centra of considerable longitudinal extent.

There are usually two articular facets for the ribs, both situate on the neural transverse process. In *Mastodonsaurus*, however, the lower facet is continuous with the centrum ‡; and an example of the vertebral column of

* Quart. Journ. Geol. Soc. vol. xix. p. 67 (note) (1863).

† *L. leptognathus* (Owen, 'Trans. Geol. Soc.' vol. vi. t. xlv. figs. 5–8).

‡ Paläontologie Würtembergs, t. iv. fig. 8, and p. 58 (1844).

a Labyrinthodont from the Northumberland coal-field, which Mr. T. P. Barkas has permitted us to study, seems to exhibit the same feature*.

The superior and inferior spinous processes differ greatly as to length and form. In *Archegosaurus* and many others the spinous processes, both superior and inferior, are broad and quadrilateral. In *Urocordylus* and *Œstocephalus*† the superior and inferior spinous processes of the long tail are elongate and fan-shaped, being dilated, compressed, and truncated at the distal ends, so as to suggest great swimming-power.

The inferior arches are rarely seen to advantage; but in *Archegosaurus* they are large and complete, forming a spacious canal for the caudal vessels‡.

By study of young specimens of *Archegosaurus* it has been ascertained that the superior vertebral arches ossify before the inferior, and the anterior vertebræ before the posterior. Von Meyer thinks it probable that the superior arches were ossified to a considerable extent before the close of embryonic life §.

The atlas of *Mastodonsaurus* has been figured and described ‖. It is a flattish disk, presenting two oval cavities to the occipital condyles, and nearly smooth behind. Above, the laminæ enclose the chief part of the spinal foramen, ascending to form a spinous process of considerable but unknown height. A cavity for the odontoid occupies nearly the centre of the bone, between the articular facets, and communicates with the spinal foramen by a constricted passage.

Ribs.—No Labyrinthodont is known to have been devoid of well-developed ribs. They are generally attached to all the vertebræ in advance of the pelvis, and in some cases, at least, are present in the anterior part of the caudal region also.

As to form, they are usually compressed (transversely to the axis of the trunk) at either end, but are nearly cylindrical in the centre of the shaft. They are short, relatively to the probable dimensions of the thorax, and strongly curved. A capitulum and tuberculum are present in all well-preserved examples. Both articular surfaces are slightly concave and adjacent, and in most of the Labyrinthodonts both appear to have articulated with the vertebral transverse process; a notch or groove commonly separates them, and is usually continued for some distance along the shaft of the rib.

Sternal or abdominal ribs are not known to occur in this order.

It appears from the extensive suite of specimens described by Von Meyer¶, that the ribs of *Archegosaurus* were developed and partially ossified at a very early period, perhaps before the close of embryonic life. Some very young

* This fossil is named *Macrosaurus polyspondylus* by Mr. Barkas; but its generic or specific distinctness cannot as yet be affirmed.

† It is impossible not to suspect the identity of these genera. Prof. Cope remarks (Trans. American Phil. Soc. vol. xiv. N. S. p. 16):—"It [*Œstocephalus*] differs [from *Urocordylus*] only in the presence of elongate lizard-like ribs, and in the absence of 'oat-shaped scales' of the lower surfaces." But *Urocordylus* has slender ribs, of more than usual length. Were the absence of oat-shaped scutes from the ventral surface of the American examples of *Œstocephalus* established, little could be proved thereby. In the Northumberland coal-field Labyrinthodonts abound, yet the scutes appear not to have been hitherto discovered. On the following page of his 'Synopsis,' however, Prof. Cope says of *Œstocephalus*:—"The skin has been occupied by a great number of closely packed, curved, spine-shaped scales. They have occupied the ventral integument, passing from the median line of the belly outwards and posteriorly, having acute tips, which may or may not have penetrated the skin on each side." This structure cannot differ essentially from the chevron pattern of oat-shaped scutes found in *Urocordylus*.

‡ Von Meyer, 'Reptilien' &c., p. 107, t. xii. fig. 7.

§ Reptilien &c., p. 29.

‖ Paläontologie Würtembergs, t. v. figs. 4, 5, and p. 67.

¶ Reptilien &c., p. 33.

examples afford evidence of cartilaginous vertebral extremities, this evidence consisting of the separation of the proximal ends of the ribs from the vertebral column by a regular interval, and the hollowing-out of the ends as if for junction with cartilage *. At this stage a transverse process may be seen to project for a short distance from the lamina of the corresponding superior arch. The junction is not completed by a true bony articulation until the animal is nearly adult.

Shoulder-girdle.—The shoulder-girdle of the Labyrinthodonts includes three thoracic plates (which represent the clavicles and interclavicles), one or more scapular bones, and a coracoid. In form and arrangement these parts differ much from the pectoral arch of any recent Amphibian, but correspond generally with the structure which prevails in some Reptilia, such as the Lacertilia (e. g. *Trachydosaurus*, *Monitor*, *Iguana*) and the Ichthyosauria. The resemblance between the shoulder-girdle of the Labyrinthodonts and that of the Ichthyosauria is close and striking.

The thoracic plates are eminently characteristic of the true Labyrinthodonts. They are three in number, a median and two lateral. The median plate is elongated, and more or less rhomboidal; it is placed longitudinally. On each side it is overlapped by the lateral plates to a considerable degree, especially upon the antero-external borders; and frequently only the hinder end is exposed. The free part ordinarily exhibits sculpturing. The lateral plates have been compared as to form to the elytra of beetles. They are often, but not always, triangular in form—the base, which is directed inwards, being rounded, and the remaining sides set at an angle of 90 degrees or more. A sculptured pattern is sometimes seen to radiate from the angle; and this is the thickest and strongest portion of the plate.

The thoracic plates extend nearly from side to side, and may protect a third, or even more, of the ventral surface of the trunk. They vary greatly as to form and relative size.

The median plate represents the interclavicle, and the lateral plates the clavicles. All are dermal bones, forming no part of the true axial and appendicular endo-skeleton.

Behind these (that is, nearer to the pelvic arch) and in a deeper plane are the remains of the scapula and coracoid. These are most completely preserved in *Archegosaurus*, and much resemble the corresponding parts in the recent Siren.

The coracoid is ventrally situate, semilunar in form, having a concave thickened posterior margin, a thickened postero-external angle, and a regularly rounded anterior edge. There is no reason to suppose that this does not retain, approximately, its natural position. On the outer side of the coracoid there lies in an oblique position a long, narrow, flattish slip of bone; its posterior end, which is expanded and a little twisted, is adjacent to the postero-external angle of the coracoid; while the other or anterior end is produced at great length forwards and inwards, generally passing beneath the thoracic shield. Another bone, which may, however, be a detached part of the same, is seen in several examples of *Archegosaurus*. It lies somewhat internal to the last described bone, immediately behind the edge of the thoracic plates, and has a slightly expanded end †. There can be little doubt that we have here a scapula, and probably a suprascapular bone also. The glenoid cavity was probably cartilaginous in *Archegosaurus*, and is not shown in the

* Reptilien &c., t. iv. fig. 5, and t. vi. fig. 10.

† This end is directed backwards (*i. e.* towards the pelvis). The other extremity is not shown.

fossil specimens. It seems to have been at the postero-external angle of the coracoid.

Von Meyer and Burmeister have described the bone here named coracoid as the scapula, and the scapula (or suprascapula) as the coracoid.

The coracoid of *Trematosaurus* is known; it closely resembles that of *Archegosaurus*. A detached scapula of *Pholiderpeton* has also occurred. No scapula or coracoid has been found in the other genera. The thoracic plates of *Mastodonsaurus*, *Trematosaurus*, *Archegosaurus*, *Loxomma*, *Pholidogaster*, *Pteroplax* (?), *Keraterpeton*, and *Urocordylus* (?) are known; but none have hitherto been discovered in any of the species which constitute the "Microsauria" of Dr. Dawson.

Pelvic Girdle.—*Archegosaurus* still remains the only source of exact knowledge respecting the pelvis of the Labyrinthodonts. The ischia are elongate, flattened bones, which meet along the middle line. Their antero-external angles are overlapped by the expanded ends of the hatched-shaped ilia, while the straight shafts of these latter bones are continued backwards, outwards, and upwards. Similar, but larger, hatchet-shaped ilia occur in the Newcastle coal-field. They may belong to *Loxomma* or *Anthracosaurus*. The connexion of the ilium with the vertebral column appears to have been very slight; and there is no indication of specially modified sacral vertebræ. The pubis is straight, and has much of the form of the femur or humerus, being narrowed at the middle and broad at each end. The situation and composition of the acetabulum is unknown.

It would be highly interesting to know that the ilium described and figured by Professor Owen* was actually the ilium of *Labyrinthodon pachygnathus*, or of any other Labyrinthodont; but the evidence derived from the place of discovery is not cogent, and the bone is remarkably reptilian in character.

Bones of the Limbs.—In the Carboniferous Labyrinthodonts the bony elements of the limbs of vertebrates higher than fishes appear in their most generalized form. The manus and pes are pentadactyle, and there is but little differentiation of the digits. Each of the long bones has expanded ends, and is contracted towards the middle of the shaft. In the Carboniferous species the articulations seem to have been very lax. There are no articular processes, condyles, cups or trochleæ; and the bones appear to have been connected in the simplest way, by ligaments and integument. The long bones of *Hylonomus* and some other "Microsauria" are tubular, and consist of a uniform osseous crust, enclosing a central cavity, which in the living animal was probably occupied by cartilage†. In several other Labyrinthodonts, however, of Carboniferous age, true cancellous tissue is present in the long bones.

If the limb-bones attributed to *Mastodonsaurus* have been so determined correctly, it would appear that in the Triassic Labyrinthodonts the long bones and phalanges were, as in the Carboniferous species, dilated at the ends and contracted in the centre. There is no indication of bony epiphyses; and the muscular impressions are few and simple‡.

In all the species whose limbs are accurately known from their occurrence together in the same matrix and in something like the natural position, the corresponding parts of the fore and hind limbs (*e. g.* the femur and hu-

* Trans. Geol. Soc., 2nd series, vol. vi. p. 533, t. xlv. figs. 16, 17.

† A humerus of *Dendrerpeton* shows cancellous tissue towards the extremities (Dawson, 'Acadian Geology,' 2nd ed. p. 365).

‡ Paläontologie Würtembergs, t. iii. figs. 4–8.

merus) are very similar in form and present no uncommon difference of size*. The hinder limb is larger and stronger than the other, as is usual with quadruped vertebrates. On the whole the structure and proportions of the extremities of Labyrinthodonts are similar to those of urodele Amphibia, and indicate low-bodied aquatic animals.

It is well known that the examination of the bones found in the Keuper of Leamington and Warwick, together with a comparison of the footprints named *Cheirotherium*, led Professor Owen to the belief that *Labyrinthodon* exhibited a striking disproportion between the fore and hind limbs. This view accords well with the opinion that the Labyrinthodonts were anurous Batrachia. But such a disproportion implies more than a near affinity with the Batrachia: it is in this class (Amphibia) a mechanical provision for activity in leaping; and the inference from Professor Owen's hypothesis would be that the Triassic Labyrinthodonts at least had in some measure the habits of the frog. The supposition will not stand a moment's consideration. That a *Labyrinthodon*, with its greatly expanded and prolonged head could have leaped a yard without a severe shock is improbable. But if we suppose that it possessed the thoracic plates and the loosely articulated shoulder-girdle of other Triassic Labyrinthodonts, and if, with Professor Owen, we interpret the structure of its extremities according to the Cheirotherian footprints, the difficulty is greatly increased. The *Labyrinthodon* would be a leaping animal of gigantic size, weighted with protective scutes, having little-expanded toes, and not provided, to our knowledge, with a single one of those special provisions which enable large animals to leap great distances with safety.

No one will explain the assumed disproportion of fore and hind limbs as indicative of peculiar browsing or climbing propensities, such as those attributed to *Iguanodon* or *Hadrosaurus*. The aquatic and predatory character of the Labyrinthodonts is well established.

Since the hypothesis under discussion involves such difficulties, it will be desirable to reexamine the ground upon which it rests.

Professor Owen's position is this:—*Anisopus scutulatus*, a presumed Labyrinthodont, has a hind limb at least twice as large as the fore limb.

An ilium and head of femur, presumed to belong to *Labyrinthodon pachygnathus*, are greatly larger in proportion than a humerus referred to the same species.

In some Cheirotherian (presumed Labyrinthodont) footprints the tracks of one foot are much larger than those of the other.

The species of *Labyrinthodon* differ considerably in size, as also do the footprints of *Cheirotherium*.

It is hardly necessary to discuss the distinctness of the species of *Labyrinthodon* or of *Cheirotherium*. The whole weight of the argument rests upon the suppositions that (1) the bones named *Anisopus scutulatus*, (2) the ilium and femur found at Warwick, (3) the humerus found separately at the same place, (4) the footprints named *Cheirotherium*, belong to Labyrinthodonts—and, further, that the ilium and humerus found at different times in the same quarry belong to the same individual, or to individuals of the same species and age.

This chain of suppositions has not been strengthened by the further evi-

* There is no conclusive evidence that *Anisopus* is labyrinthodont. The rhomboidal sculptured scute attached to the slab containing this specimen might seem confirmatory of Prof. Owen's determination; but, besides the Crocodilia, the Scelidosauridæ had dermal armour.

dence brought to light since the date of Professor Owen's memoir. We still know very little about the limbs of Triassic Labyrinthodonts. What is known of the limbs of the Carboniferous species does not at all agree with the determinations in question. But it is now placed beyond dispute that in Triassic rocks, and in this very Keuper quarry at Warwick, the remains of Dinosauria occur. The ilium assigned to *Labyrinthodon pachygnathus* * agrees with the ilium of Deinosauria in the remarkable projection of the bone in front of the acetabulum, and in the character of the acetabulum itself. It wants, it is true, the pre- and postacetabular processes of a well-characterized Dinosaurian ilium; but in no particular does this bone agree with the ilium of any known Labyrinthodont. There is nothing in the structure of any one of the limb-bones or vertebræ attributed to *L. pachygnathus* which does not accord at least as well with the Dinosauria as with the Labyrinthodonts†. Nor is there a single distinctive Labyrinthodont feature about *Cheirotherium*. Some of the footprints included in this heterogeneous group may have been Labyrinthodont; but others are, not improbably, Dinosaurian‡. Shortness or deficiency of the outer digits §, and inequality of fore and hind limb, are characteristic of this reptilian order ‖.

It may be said, summarily, that the Labyrinthodonts of the Coal-measures had the limbs of aquatic animals similar to the urodele Amphibia, and that the limbs of the Triassic species are practically unknown.

No limbs have been discovered belonging to specimens of *Ophiderpeton*, although several examples belonging to this genus have occurred in the coal-fields of Kilkenny and Northumberland.

Hyoid.—We have no certain knowledge of the hyoid of any Labyrinthodont. A fragment of a styloid bone which sometimes appears between the parasphenoid and the median thoracic plate of *Archegosaurus*, associated with one or two pairs of lateral appendages, may belong here.

Branchial Arches.—Goldfuss ¶ first observed that some young examples of *Archegosaurus* exhibit distinct traces of branchial arches; and this determination is confirmed by Von Meyer. The evidence consists of minute ossicles lying scattered in the region of the throat, between the thoracic plates and the skull. Some of the ossicles exhibit a pectinate edge. They are variously discoidal, semilunar, or quadrangular in outline, but always flattened. Von Meyer believes that the branchial arches were attached to the hyoid, and were disposed in two or more curved rows. Traces of branchial arches have only been detected in young specimens; and they do not increase in size with

* "The remarkable ilium ascribed to *Labyrinthodon pachygnathus* is also a reptilian bone, intermediate in its characters between the ilium of a Teleosaurian and that of a Lizard."—Huxley, 'Geol. Journ.' vol. xxvi. p. 47 (1870).

† The fragmentary vertebra ascribed by Prof. Owen to *L. pachygnathus* is believed by Prof. Huxley to be Dinosaurian (Quart. Journ. Geol. Soc. 1870, vol. xxvi. p. 47).

‡ The Cheirotherian footprint figured and described by Prof. W. C. Williamson (Quart. Journ. Geol. Soc. vol. xxiii. p. 56) exhibits numerous impressions of scales. This is a reptilian feature, though not conclusive against the Labyrinthodont supposition.

§ *Iguanodon* has left large three-toed impressions in the Wealden. *Scelidosaurus* had four toes and a rudimentary fifth.

‖ "From the great difference in size between the fore and hind limbs, Mantell, and more recently Leidy, have concluded that the Dinosauria (at least *Iguanodon* and *Hadrosaurus*) may have supported themselves for a longer or shorter period upon their hind legs. But the discovery made in the Weald by Mr. Beckles, of traces of large three-toed footprints, of such a size and at such a distance apart that it is difficult to believe that they can have been made by any thing but an *Iguanodon*, lead to the supposition that this vast reptile, and perhaps others of its family, must have walked temporarily or permanently upon its hind legs."—Huxley, 'Quart. Journ. Geol. Soc.' vol. xxvi. p. 18 (1870).

¶ Beiträge, p. 8.

age. It is therefore highly probable that the branchial respiration of *Archegosaurus* was not persistent, but was restricted to the larval state.

It is somewhat remarkable that while Von Meyer interprets these remains as traces of a branchial apparatus, he nevertheless refuses to recognize the zoological significance of such a structure. His comment is, that the hyoid itself is a relic of branchial apparatus, yet its presence in the higher vertebrates is not allowed to interfere with their systematic arrangement *. The serial homology of the hyoid and branchial arches, upon which Von Meyer perhaps relies, would prove too much for his purpose. The study of development shows that "the branchial arches have the same morphological value as the hyoid, and the latter as the mandibular arc;" † further, that the trabeculæ cranii ("Schädelbalken" of Rathke) are serially homologous with the visceral arches. If the argument rests, not upon homology, but upon function, it is clear that the common association of branchiostegal rays with the hyoid arch in branchiate vertebrates would not justify us in describing a part whose function in the higher classes is so various as a remnant of branchial apparatus. It would be as reasonable to speak of the humerus as a relic of a swimming-organ.

Until an example is cited of osseous branchial arches in an abranchiate vertebrate, we may regard the presence of such a structure in the young *Archegosaurus* as a remarkable Amphibian character.

Dermal Armour.—In nearly all the known species of Carboniferous Labyrinthodonts a ventral armour has been found. The armour consists of very numerous, elongated, osseous scutes, and is generally, perhaps always, confined to the inferior surface of the body between the fore and hind limbs. The scutes are usually disposed in oblique rows, which meet at an angle along the middle line and make a chevron pattern. Such an arrangement occurs for example in *Pholidogaster* ‡, *Urocordylus* §, and *Ichthyerpeton* ‖. In *Archegosaurus* the pattern is reversed in the hinder part of the trunk, so that the rows of scutes in the front part are approximately at right angles to those placed further back on the same side.

Lepidotosaurus, if a true Labyrinthodont, presents striking deviations from the rest in the character of its dermal armour. But there are many difficulties in the way of obtaining an adequate knowledge of this remarkable form. The state of the single specimen hitherto discovered does not permit more than a superficial examination. Messrs. Hancock and Howse ¶ have done all that care and skill can do towards elucidating its structure; and we cannot but accept, provisionally, their decision that it must be placed among the Labyrinthodonts. Nevertheless the difficulties are considerable, especially with respect to the scales or scutes. The oblique and uniform direction of the very numerous and prolonged rows of scales is an argument against Prof. Huxley's view that they represent a ventral armour shifted (after death and some amount of decay) to one side. Upon that supposition we should expect to find the rows of scales either transverse (an arrangement not yet discovered in any Labyrinthodont) or converging from opposite sides to a straight line

* "Genau genommen liesse sich selbst das Zungenbein als Ueberrest einer früheren Athmungsvorrichtung betrachten, und doch wirkt dessen Gegenwart nicht störend bei der Classification der höheren Thiere."—Reptilien aus der Steinkohlenformation, p. 36.

† Huxley, Croonian Lecture, 'Proc. Roy. Soc.' vol. ix. p. 433.

‡ Huxley, 'Quart. Journ. Geol. Soc.' vol. xviii.

§ From undescribed specimens in the British Museum from Kilkenny.

‖ Huxley, 'On a Collection of Fossil Vertebrata' &c., p. 18.

¶ Nat. Hist. Trans. Northumberland and Durham, vol. iv. p. 219; and Quart. Journ. Geol. Soc. vol. xxvi. p. 556 (1870).

(as in *Archegosaurus*, *Urocordylus*, &c.). Moreover the scales are quite unlike those of any well-established Labyrinthodont genus, and both in disposition and extent they are anomalous. The ribs and the (presumed) long neck are also difficult to reconcile with the Labyrinthodont character of this interesting fossil.

As to form and size the scutes of the Labyrinthodonts vary much. They may be oval, rhomboidal, lancet-shaped, or oat-shaped. They may be as much as two inches long, or so minute as to be barely visible. When thick and large, they exhibit a cancellous bony structure in cross section ; in many cases they are coated with an enamel-like layer ; and when the scute is very thin, this layer seems to compose its entire substance.

Such an armour cannot be exactly paralleled by any thing known among recent Amphibia or Reptilia. The Crocodilia have bony scutes, which in *Caiman* and *Jacare* lie along the belly ; but neither these, nor the bony scales of certain lizards (*Ophisaurus*, *Pseudopus*, *Cyclodus*), are restricted to the ventral surface. The dermal ossifications of Chelonia are dorsal as well as ventral. In a few recent Batrachia (*Ceratophrys cornuta*, *C. ornata*, *Brachycephalus ephippium* *) there is a partial dorsal shield. In the cutis of some Gymnophiona there are minute flexible scales †.

Granular, shagreen-like scales have been found to cover other parts of the body of a few Labyrinthodonts. Dr. Dawson has figured and described a remarkable covering of horny scales as forming dorsal and lateral appendages to *Hylonomus Lyelli* ‡ ; but there does not appear to be conclusive evidence as to their disposition.

Nature of Food and Mode of Life.—The character of the teeth and the structure of the skull, so similar as a prehensile and masticatory organ to the skulls of Crocodilia, indicate plainly that the Labyrinthodonts were predacious animals. Patches of Acanthodian scales found on the inner side of the ventral armour have led Burmeister to suppose that *Archegosaurus* at least was a fish-eater §. Von Meyer quotes instances of the occurrence of fragments of Archegosaurian plates in coprolites assigned to the same species. Dr. Dawson has found near the bones of *Hylonomus* portions of coprolite containing remains of insects and myriapods ‖ ; while numerous bones of the same Labyrinthodont genus occur in coprolitic masses attributed to *Dendrerpeton* ¶.

The Amphibian affinities of Labyrinthodonts and the presence of a branchial apparatus in the larva render it plain that these animals were wholly aquatic in their earliest stages. The proportions of the skull, and the weak limbs of all the known Carboniferous species, at least, furnish reasons for believing that throughout life they frequented water, and sought their food in it. The analogy of all other Amphibia would lead us to suppose that the Labyrinthodonts were fluviatile, not marine. The character of the deposits in which their remains are usually found confirms this view.

There is ground for believing that the largest Labyrinthodonts attained a length of seven or eight feet, though accurate data are wanting. Some of the smaller examples, though adult and perfect, do not exceed as many inches in length.

Zoological Affinity.—In the present state of palæontological knowledge it

* Formed in this case by the dilated processes of six dorsal vertebræ.

† These are wanting in *Cæcilia annulata*.

‡ Acadian Geology, 2nd ed. pp. 372, 375, fig. 144 ; and restoration, p. 352.

§ *Archegosaurus*, p. 60, t. iii. figs. 3, 4. Von Meyer regards this as doubtful (Reptilien &c. pp. 6, 7).

‖ Acadian Geology, 2nd ed., p. 376. ¶ Ibid. p. 379.

would not be easy to frame an unexceptionable statement as to the zoological position of the Labyrinthodonts. Were they now alive, they would doubtless be considered Amphibia. The double occipital condyle, the parasphenoid ossification, and the presence of a branchial apparatus in the young or larval state would overpower such considerations as the Crocodilian scutes or the Crocodilian character of the exposed parts of the cranium. But in dealing with a long extinct group we are not altogether justified in trusting simply to those characters which suffice to define the classes and orders of existing animals. On any theory of descent with modification there would thus be danger of coordinating an extinct group with its own modified or differentiated descendants. Even if all such theories be discarded, it remains to be shown that we can legitimately impose a division into Classes and Orders based on the study of recent Vertebrates upon generic forms of Carboniferous or Triassic age.

Palæontologists have not not held themselves bound to refer every ancient type to existing classes. The Labyrinthodonts were regarded by Goldfuss as intermediate between Crocodilia and Lacertilia, afterwards as intermediate between Ichthyoda (Perennibranchiata), Crocodilia, and Lacertilia. Burmeister considers them to have affinity to all the orders of Amphibia (Amphibia + Reptilia), taking the same view of the position of the Trilobita among Crustacea. Now that the writings of Darwin have given greater definiteness and coherence to such views of zoological relation, and have rendered it possible to regard all natural history as a pedigree, speculation has become bold indeed. Hæckel* is able to assure us that the Ganocephala diverged from the Perennibranchiate Amphibia (which make the thirteenth step in the descent of man) during the Carboniferous period, that they developed *Proterosaurus* and the Labyrinthodonts (branches which soon died out), and that the Ganocephalous line is continued down to our own day by the Gymnophiona. It is hardly necessary to point to Hæckel's "Stammbaum" of the Ganoid Fishes and the Dipnoi, which recent discoveries have done so much to impugn, in order to inspire distrust of these "far-reaching Phylogenies." Speculation as to the derivation of ordinal types, though undoubtedly legitimate, has hitherto proved extremely hazardous.

If we restrict ourselves to such statements as may be maintained by evidence, we can at present say nothing more definite than this:—that the Labyrinthodonts were in nearly all important respects like recent Amphibia; that their most striking peculiarities are those which adapted them for a predatory life; that certain species, or certain details of structure, recall the recent Urodela, others the Gymnophiona, while the resemblance to the Batrachia is hardly ever so close as to one or other of the lower orders of existing Amphibia.

Distribution.—Remains of Labyrinthodonts have occurred in England, Scotland, Ireland, Germany, Russia, Central India, South Africa, Australia, and North America. In the British Museum and in the Museum of the College of Surgeons undescribed specimens of Labyrinthodonts are preserved, which have been obtained from the Rhætic beds of the Severn. One genus (*Rhinosaurus*) has occurred in the Oolitic strata of the Government of Simbirsk (Russia). It is there associated with Ichthyosauria and *Gryphæa dilatata*.

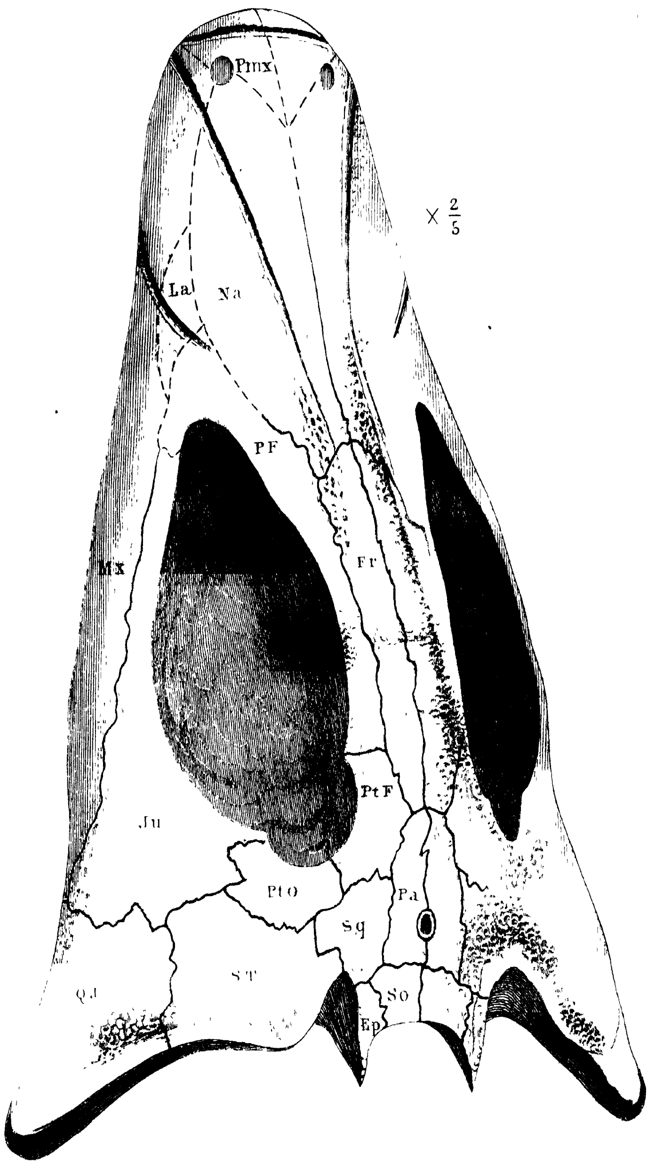
* Schöpfungsgeschichte, 2nd ed: compare pp. 524, 586, and tab. xii.

Table of Distribution.

	Carboniferous.	Permian.	Triassic.	Rhætic.	Jurassic.
England	Anthracosaurus, *Hux.* Batrachiderpeton, *Han.* Loxomma, *Hux.* Ophiderpeton, *Hux.* Pholiderpeton, *Hux.* Pteroplax, *Han.* Urocordylus, *Hux.*	Dasyceps, *Hux.* Lepidotosaurus, *Han.*	Labyrinthodon, *Ow.* Diadetognathus, *Miall.* Mastodonsaurus, *Jaeg.*	Undescribed specimens.	
Scotland	Anthracosaurus, *Hux.* Loxomma, *Hux.* Pholiderpeton, *Hux.* Pholidogaster, *Hux.* Pteroplax, *Han.*				
Ireland	Dolichosoma, *Hux.* Erpetocephalus, *Hux.* Ichthyerpeton, *Hux.* Keraterpeton, *Hux.* Lepterpeton, *Hux.* Ophiderpeton, *Hux.* Urocordylus, *Hux.*				
Germany.........	Apateon, *Meyer.* Archegosaurus, *Goldf.* [Osteophorus, *Meyer.*]		Capitosaurus, *Munst.* Mastodonsaurus, *Jaeg.* Metopias, *Meyer.* Trematosaurus, *Braun.* Xestorrhytias, *Meyer.*		
Russia	....	Zygosaurus, *Eichw.*	Chalcosaurus, *Meyer.* Melosaurus, *Meyer.*		Rhinosaurus, *Waldh*
Central India......	....	....	[Brachyops, *Ow.*] Gonioglyptus, *Hux.* Pachygonia, *Hux.*		
South Africa	....	....	Micropholis, *Hux.*		
Australia...........	....	....	[Bothriceps, *Hux.*]		
North America.	Amphibainus, *Cope.* Baphetes, *Ow.* Brachydectes, *Cope.* Colosteus, *Cope.* Dendrerpeton, *Ow.* ? Eosaurus, *Marsh* ? Hylerpeton, *Ow.* ? Hylonomus, *Daws.* ? Molgophis, *Cope.* Œstocephalus, *Cope* (Urocordylus). Raniceps, *Wyman* ? Sauropleura, *Cope.* Ichthyocampsa, *Cope.*		Dictyocephalus, *Leidy.* Eupelor, *Cope.* Pariostegus, *Cope.*		

*** No opinion is for the present expressed as to the validity of these genera. The systematic position of those marked ?, and the stratigraphical position of those included in brackets, have been questioned.

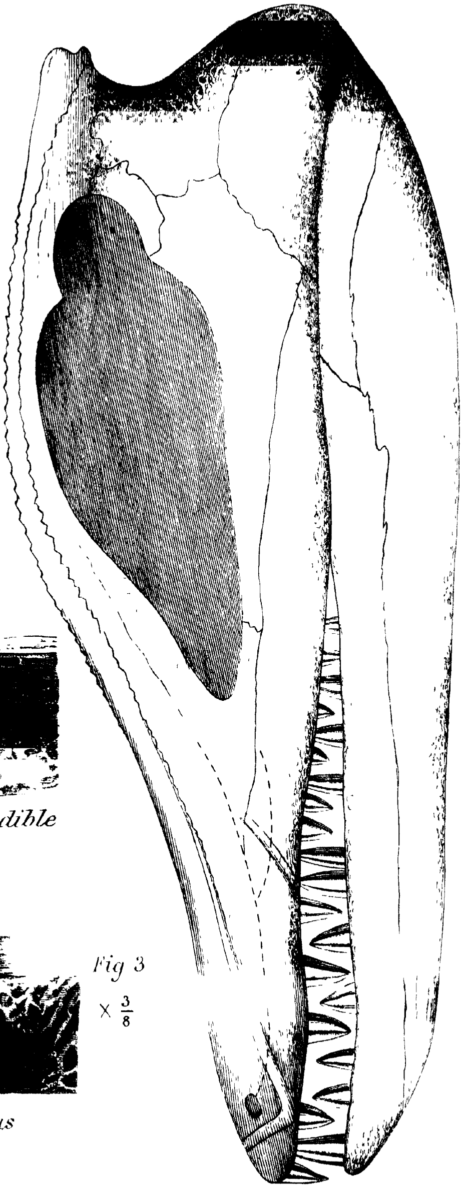
Brit. Assoc Report on Labyrinthodonts



Skull of Loxomma (restored)

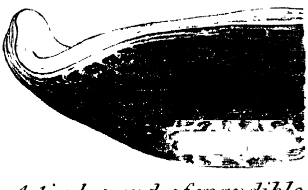
Brit. Assoc Report on Labyrinthodonts.

Fig. 1.
X $\frac{2}{5}$



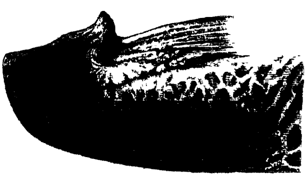
Skull of Loxomma (side-view)

Fig 2 X $\frac{3}{8}$



Articular end of mandible
Loxomma.

Fig 3
X $\frac{3}{8}$

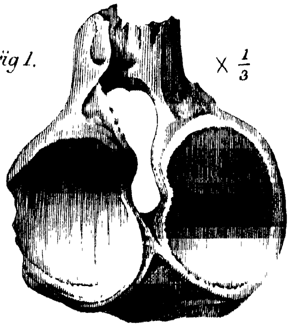


Diadetognathus

Engraved by Chas. Ingram

Brit. Assoc Report on Labyrinthodonts.

Fig 1. × 1/3



Atlas of Mastodonsaurus

Fig. 2.

Cervico-dorsal vertebræ of Mastodonsaurus (restored) × 1/2

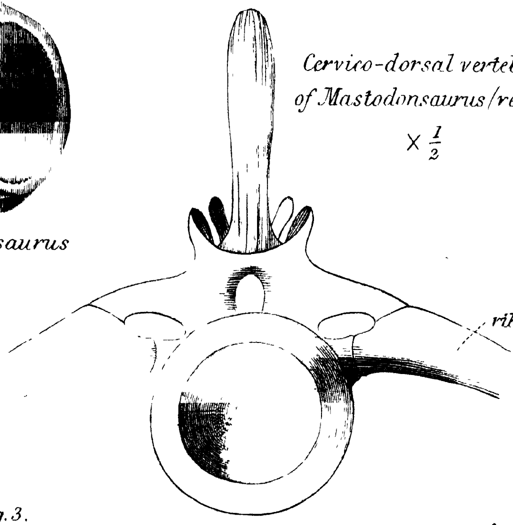
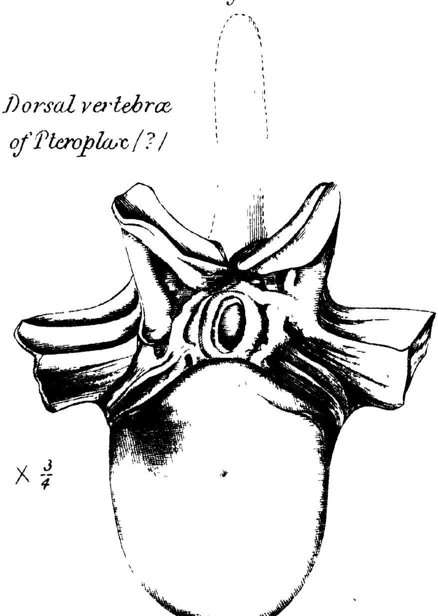


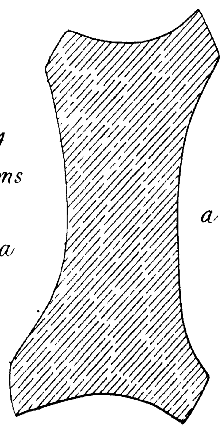
Fig. 3.

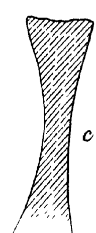
Dorsal vertebræ of Pteroplax (?)

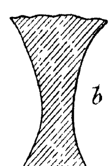


× 3/4

Fig. 4 Sections of Centra × 3/4







Note.—Since the preceding Report was presented, additional information has been obtained from various sources, particularly by means of a detailed examination of the Labyrinthodont fossils in the Museum at Warwick. The nature of the mandibular articulation of *Mastodonsaurus*, for example, is more clearly revealed by undescribed specimens in the Warwick collection than by any of the Würtemberg fossils. A special paper, containing an account of the results arrived at, will shortly be published. Some notice of the structure of the osseous ear-chamber, as exhibited by the large skull of *Capitosaurus* from the Keuper sandstone of Würtemberg, should have been included in the Report. The essential facts are given by Quenstedt (Die Mastodonsaurier im grünen Keupersandsteine Würtemberg's sind Batrachier, p. 14, t. ii. fig. 1, and t. iii. figs. 16, 18). On a future occasion the Committee hope to give the results of a microscopic examination, now in progress, of the teeth of various Labyrinthodont genera.

January 1874.

EXPLANATION OF PLATES I.-III.

PLATE I.

Skull of *Loxomma* (restored). The contours are chiefly taken from a fine uncompressed specimen in the possession of Mr. George Maw, F.L.S.

PLATE II.

Fig. 1. Side view of skull of *Loxomma*.
2. Posterior extremity of mandible of *Loxomma*, showing the absence of a post-articular process (Report, p. 237).
3. Posterior extremity of mandible of *Diadetognathus*, showing a well-developed post-articular process.

PLATE III.

Fig. 1. Atlas of *Mastodonsaurus*, front view (Paläontologie Würtembergs, t. v. fig. 4).
2. Restored cervico-dorsal vertebra of *Mastodonsaurus*, seen from before, showing the articular facet upon the centrum (Report, p. 239).
3. Dorsal vertebra of *Pteroplax* (?), seen from behind (Hancock and Atthey, Nat. Hist. Trans. Northumberland and Durham, vol. iii. t. ii. fig. 2). The vertebra is slightly restored, and shows the two facets upon the transverse process (Report, p. 239). For comparison of vertebra of *Anthracosaurus* (?), see Huxley, 'Quart. Journ. Geol. Soc.' vol. xix. p. 63.
4. Antero-posterior section of vertebral centra. (a. *Mastodonsaurus*. b. *Pteroplax*. c. *Pholiderpeton*.)

Report of the Committee appointed to construct and print Catalogues of Spectral Rays arranged upon a scale of Wave-numbers, the Committee consisting of Dr. HUGGINS, J. N. LOCKYER, Professor REYNOLDS, Professor SWAN, *and* G. JOHNSTONE STONEY (Reporter).

THE Committee, appointed to construct and print catalogues of spectral lines arranged upon a scale of wave-numbers, had hoped to present the catalogue of solar lines, and of a large number of metallic lines, at the present Meeting of the Association; but a delay having arisen about the engraving of the maps which should accompany the catalogues, they have not been able to go to press in sufficient time.

The whole of the solar spectrum is now ready for the printer; and the reduction of those positions of metallic lines which Thalén determined by the

method of direct superposition upon the solar spectrum is in a forward state. The solar lines have been thrown into the groups which catch the eye in observing the spectrum; and the position of each line has been corrected for the dispersion of the air. Both Kirchhoff's arbitrary number and Ångström's determination of wave-length will be given along with the wave-number for each line; so that it is hoped that, when these catalogues are printed, observers will find in them, in a collected form, the best materials which yet exist for the identification of lines, and for reducing fresh determinations, either to wave-lengths in air or wave-numbers *in vacuo*.

The Committee had taken Ångström's determinations of the wave-lengths of about a thousand solar lines, published in his 'Recherches sur le Spectre Solaire,' as the foundation of their catalogues. They are therefore glad to be able to state, on the authority of the Astronomer Royal, that his criticism of Ångström's labours in the Philosophical Transactions for 1872, pp. 90 & 109, refers to preliminary measures made by Ångström in 1863 with imperfect apparatus, and does not affect the determinations which have been relied on by the Committee.

The small final corrections mentioned by Ångström at p. 29 of his memoir have been applied throughout to the numbers of his catalogue. The correction for each line was ascertained by a diagram constructed by plotting down the corrections corresponding to the lines of the select list which he gives on pp. 31 & 32. The Association Catalogue may therefore be regarded as representing Ångström's work in its finished state.

The corrections to be applied for the dispersion of the air have been deduced from Ketteler's determinations of the refractive indices of air corresponding to the positions of the lithium, sodium, and thallium lines. These give only three points on the curve; but as they lie nearly in a straight line when referred to a scale of wave-numbers, the extension to the limits of the visible spectrum is tolerably safe. Nevertheless it would be very desirable that a determination of this important correction should be made, extending over the whole spectrum. One of the members of the Committee hoped to execute this work, and planned the apparatus which seemed necessary; but he could not command sufficient time to carry out his intention.

Since your Committee have not finished the task intrusted to them, they recommend that they be reappointed; they would request that Messrs. Spottiswoode and De La Rue be invited to serve along with them.

Report of the Committee, consisting of Sir JOHN LUBBOCK, *Bart.*, Professor PHILLIPS, Professor HUGHES, *and* W. BOYD DAWKINS, *Secretary, appointed for the purpose of exploring the Settle Caves. Drawn up by* MR. BOYD DAWKINS.

THE Committee appointed by the British Association at the last Meeting, at Brighton, to cooperate with the Settle-Cave Committee in carrying on the exploration of the Victoria Cave, has expended the grant intrusted to them, with but negative results. Since the last Report was published, in which the discovery of the Pleistocene cave-earth underneath the grey clay at the entrance was recorded, their attention was directed to the examination of the

Pleistocene stratum and its relation to the deposits above and below. A passage was cut through the talus of angular detritus fallen from the cliff at the same level as the cave-earth, which proved that the detritus graduated in its lower part into a clay containing stones, among which glaciated Silurian grit-stones were recognized on 3rd November, 1872. These were close to a large mass of fallen rock which formed the left-hand side of the passage that had been cut at the entrance, the right-hand consisting of the solid limestone wall of the cave. They rested at about the same level as the stratum containing the cave-mammals, and apparently were deposited on the edges of that stratum. Some of them were embedded in clay, while others, which were to be seen in the section exposed May 21 last, were free, the clay that once covered them being washed away.

At the end of the passage, and just within the entrance of the cave, a shaft was sunk, which proved that the cave-earth was only from 3 to 4 feet thick, and that it rested on a confused stratum of large limestone blocks embedded in clay both amorphous and laminated, and in some cases in sand, 7 feet thick. Below this the workmen broke into a passage, of which one side was composed of the wall of the cave.

This section revealed the fact that the laminated clay occurred at various levels, not merely above but below the Pleistocene stratum; and there seems to the Secretary (Mr. Dawkins) to be no reason why it should not be deposited now in some of the interstices between the blocks of stone *below* the Pleistocene stratum by the heavy rains.

The evidence as to the precise relation of the older deposits in the cave to the glacial phenomenon of the district is not so clear as might have been expected. The boulders may be the deposit *in situ* of a lateral moraine; or they may have dropped subsequently from a higher level. It is, however, obvious that the hyænas, bears, mammoths, and other creatures found in the Pleistocene stratum could not have occupied the district where it was covered by ice. And had they lived here after the retreat of the ice-sheet, their remains would occur in the river-gravels from which they are absent throughout a large area to the north of a line drawn between Chester and York, since they occur abundantly in the postglacial river-deposits south of that line. On the other hand, they belong to a fauna that overran Europe, and must have occupied this very region, before the Glacial period. It may therefore reasonably be concluded that they occupied the cave in preglacial times, and that the stratum in which their remains lie buried was protected from the grinding of the ice-sheet* which destroyed nearly all the surface-accumulations in the river-valleys, by the walls and roof of rock which has since been to a great extent weathered away.

The exploration of the Victoria Cave, which has hitherto yielded such interesting evidence of three distinct occupations (first by the hyænas, then by Neolithic men, and lastly by the Britwelsh), is by no means complete. The cave itself is of unknown depth and extent; and the mere removal of so much earth and clay as it is at present known to contain will be a labour of years. The results of the exploration up to the present time are of almost equal value to the archæologist, to the historian, and the geologist, and prove how close is the intimate bond of union between three branches of human thought which at first sight appear remote from each other.

* On this point see:—Pop. Sc. Rev. Oct. 1871, "Pleistocene Climate and Mammalia;" and "Classification of Pleistocene Strata," Quart. Journ. Geol. Soc. 1872, pp. 411 *et seq.*

Sixth Report of the Committee, consisting of Prof. Everett, Sir W. Thomson, *F.R.S.*, Sir Charles Lyell, *Bart., F.R.S.*, Prof. J. Clerk Maxwell, *F.R.S.*, Prof. Phillips, *F.R.S.*, G. J. Symons, *F.M.S.*, Prof. Ramsay, *F.R.S.*, Prof. A. Geikie, *F.R.S.*, James Glaisher, *F.R.S.*, Rev. Dr. Graham, George Maw, *F.G.S.*, W. Pengelly, *F.R.S.*, S. J. Mackie, *F.G.S.*, Prof. Hull, *F.R.S.*, Prof. Ansted, *F.R.S., and* J. Prestwich, *F.R.S., appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Prof. Everett, *D.C.L., Secretary.*

In last year's Report a very interesting series of observations was recorded, taken in the great well of La Chapelle at Paris, by Messrs. Mauget and Lippmann. The temperature recorded showed a tolerably regular increase, at the average rate of 1° Fahr. for every 94 feet, down to the depth of 600 metres. In comparing the temperature at this depth with that at the bottom of the well, 60 metres lower, an increase about four times as rapid was found.

The Secretary has since visited the well, and witnessed, with the advantage of Mons. Mauget's explanations, the very interesting operation of boring. From subsequent calculation, based on the data thus obtained, he has been led to concur in the explanation originally given by Messrs. Mauget and Lippmann of the abnormal increase in the last 60 metres.

The well has in its lower portion an internal diameter of 1·35 metre, and consequently a sectional area of 1·43 square metre. The boring is executed by means of a kind of chisel, whose edge is a convex arc of a circle. This chisel, with its frame, weighs 3000 kilogrammes. It is lifted and dropped by means of a series of iron rods screwed together, so as to form one rod 660 metres long. The arrangements are such that, when the chisel has been lifted ·4 of a metre from the bottom, it becomes automatically released, and falls back through this distance. The rod is then lowered after it through an equal or slightly greater distance; and, by another self-acting arrangement, the tool becomes again attached ready for a new lift. The rods are hung from one end of the beam of an engine, which takes two seconds to rise, and the same time to descend. The tool is therefore dropped fifteen times in a minute.

When this work has been going on uninterruptedly for several hours, the tool is raised above ground, and a cylindrical vessel, with a number of valves in its bottom, is lowered for extracting the mud and chips which have been produced by the operation above described. As three hours are required either for raising or lowering, a considerable portion of the twenty-four hours in each day is occupied by these subsidiary operations; and for some time previous to the observations detailed in last year's Report, the time actually spent in using the chisel was about 100 hours per week.

Hence we have the following calculation for the heat developed by the action of the tool. The weight of the tool in air is 3000 kilogrammes. Its weight in water may be assumed to be $\frac{7}{8}$ of this. Hence the work done in raising it through ·4 of a metre is 1050 kilogrammetres. Heat equivalent to this is generated in its fall; and as 424 kilogrammetres of work are equivalent to one kilogramme degree Centigrade, we have 2·48 kilogramme degrees Centigrade, or 4·46 kilogramme degrees Fahr. as the product of each fall of the tool; that is to say, one kilogramme of water would be raised in temperature 4°·46 Fahr. by the heat produced in one fall. The number of

falls in a week was $15 \times 60 \times 100 = 90{,}000$, representing 401,000 kilogramme degrees Fahr. Now, the sectional area of the well being 1·43 square metres, and a cubic metre of water being 1000 kilogrammes, the weight of water in each vertical foot is 1430 kilogrammes. The heat generated in one week's work would therefore heat, by 1° Fahr., as much water as occupies a height of $\frac{401000}{1430} = 280$ metres, and the heat generated in one day would heat a column of the height of 40 metres to the same extent. A large portion of this heat is removed by the extraction of the mud, which, on coming to the surface after its three hours' passage through the water, is found (as stated in last Report) to have a temperature of from 118° Fahr. to 194° Fahr.; but the quantity of heat remaining must assuredly be sufficient to keep the bottom of the well higher by some degrees than its natural temperature. The temperature actually observed on June 15, three days after the cessation of the boring operations, was about $2\frac{1}{2}°$ greater than the natural temperature as computed from the observations at other depths in the well; and the temperature observed on June 18 was exactly the same as on the 15th; whereas the temperature at a point 60 metres higher had fallen by ·4 of a degree. These circumstances were mentioned in last year's Report as difficult of interpretation, since one would have expected to find the greatest change at the bottom, where the artificial disturbance of the temperature had been greatest.

It must, however, be borne in mind that the operations of boring, including the raising to the surface and relowering of the boring tool and the extracting cylinder, both of which are nearly as large in section as the well itself, have a tendency to mix together the waters at different levels, and to prevent a sudden increase of temperature in approaching the bottom. Judging from the temperature of the mud, as above stated, it is probable that, during the boring operations, the solid rock surrounding the mud had, to the thickness of a few inches, a temperature not less than 100° Fahr. The temperature observed at the bottom on June 15, was $83\frac{1}{4}°$ Fahr., which, though exceeding by $7\frac{1}{2}°$ the temperature of the water 60 metres higher, must have been lower than the temperature of the rock immediately surrounding the bottom. It is therefore quite possible that after three more days of stagnation, the water at the bottom, situated between these two opposing influences, may have retained its temperature unchanged, while the water 60 metres higher showed a fall of temperature, from the discontinuance of the stirring processes which had previously enabled it to borrow heat from below.

It would appear, then, that, in computing the mean rate of increase downwards, the temperature (75°·4) observed at the depth of 600 metres (June 18), is to be preferred to the temperature observed at the bottom. Employing as the other term of comparison, the temperature 58° observed at 100 metres from the surface, the rate of increase obtained is 1° Fahr. in 28·7 metres, or in 94·3 feet. If, however, instead of the temperature at 100 metres, we employ the permanent temperature of the caves under the Paris Observatory, which is 11°·7 Cent. or 53°·1 Fahr., with a depth of 28 metres, we obtain a rate of 1° Fahr. in 25·6 metres, or 84 feet.

A few months after the observations above discussed, the boring was again interrupted by caving in, and has not yet been resumed; but preparations are being made for tubing the well through its whole depth, the previous tubing having been carried only to the depth of 139 metres. In the mean time M. Mauget has promised to take another set of observations before the water is disturbed.

[This promise has been redeemed, since the reading of the Report, by the

taking of a complete set of observations on the 15th, 16th, and 17th of October, as shown in the last of the subjoined columns:—

Depth, in metres.	1872. June 14, 15.	1872. June 17, 18.	1873. Oct. 15, 16, 17.
100	58·0	58·0	59·5
200	61·1	61·0	61·8
300	65·0	65·0	65·5
400	69·0	69·0	69·0
500	72·6	72·6	72·6
600	75·8	75·4	75·0
660	83·25	83·25	76·0

It thus appears that the abnormal elevation of temperature at the bottom due to boring, was $7\frac{1}{4}°$ Fahr.

With reference to the temperatures in the first 300 metres, Messrs. Mauget and Lippmann remark:—"When last year's observations were made, the well had been tubed to the depth of 139·15 metres, but had not been cemented. Consequently the springs which were met with in the tertiary strata, communicated, at the base of the tubes, with the water in the well. Cement has this year been poured in between all the tubes, some days before taking the temperature of the water. This operation has excluded the tertiary springs, and permitted the water of the well to resume its normal temperature."]

At Kentish-Town well, the new thermometer described in last Report was lowered by Mr. Symons to the depth of 1000 feet, on October 29th, 1872. It has been raised and read three times, with the following results:—

		°
1872.	December 23rd	67·71
1873.	April 5th	67·66
,,	July 5th	67·58
,,	September 5th	67·50

These exhibit a steady decrease, which can scarcely be attributable to errors of observation, as such errors, whether arising from change of length in the copper wire by which the thermometer is sustained, or from change in the thermometer itself, would probably have been in the opposite direction. Mr. Symons writes:—"The scale-error of the thermometer might have changed; but thermometers read higher by age, not lower, except when in vacuum-jackets, which this is not. Moreover, on roughly comparing it with my Kew Standard, I find it certainly not lower, perhaps higher; but the comparison of maximum-thermometers in shields with naked standards requires more time than I have yet been able to give."

As it will be instructive to trace these variations to their source, the thermometer has been removed for retesting, and the depth-measuring apparatus for cleaning. Mr. Symons proposes to substitute steel for copper wire, so as to reduce the amount of stretching, to substitute monthly for quarterly observations, and to attack the problem with all possible delicacy next year.

Mr. Lebour writes, with reference to the observations contained on page 133 of last year's Report, that Mr. Atkinson has "repeated the observations for temperature in the South-Hetton bore-hole, the result being that the abnormal temperature at 644 feet from the top of the boring (viz. 75°, that at 600 feet being $76\frac{1}{8}°$, and that at 670 feet being $77\frac{1}{8}°$) was found to have been quite accidental, being caused in all probability by insufficient time

having been allowed to the thermometer. The reading in these repeated experiments at 644 feet, with ample time, was a normal one between the readings above and below."

It having been ascertained that the slipping-down of the mercurial index, which has often occurred in the Phillips thermometers supplied to the Committee by Casella, was owing to their bore being less fine than in the original instrument as designed and constructed by Professor Phillips, two thermometers of finer bore were ordered from Casella; and they have been found to exhibit as much stiffness in the index as is desirable—so much so that difficulty is sometimes experienced in shaking the index down to its place when the instrument is to be set. The thermometers thus constructed have the advantage of great quickness of action, as compared with the large-bore Negrettis which are in use by the Committee; but the excessive fineness of the bore sometimes occasions difficulty in reading. The instrument, in fact, could scarcely be put into the hands of any one but a skilled observer.

Two thermometers were supplied to Mr. Willett, the Honorary Secretary for the Sub-Wealden bore which was commenced last year at Netherfield. One of them was a Negretti, the other one of the new fine-bore Phillips thermometers above described: the former alone was used. The first observation was taken in April of the present year by Mr. Bosworth, the engineer of the boring, and showed a temperature of 68½° Fahr. at the depth of 168 feet, the temperature of surface-springs as tested by the same instrument being 51° F. The Report states that the thermometer "appears to do its work well, and to give reliable results." In a second observation, taken in Mr. Bosworth's absence, the instrument was broken in hauling up. Another thermometer of the same kind was then procured from the makers; and an observation taken with it on the 2nd of August showed a temperature of 62° F. at the depth of 263 feet. No observations were taken except at the bottom, on either occasion; and the above numbers show that the heat generated by the boring-tool was sufficient to produce disturbances of temperature amounting to several degrees.

Thermometers have also been supplied for observations in two deep wells in Essex—namely, one at Witham, 660 feet deep, and another at Harwich, originally about 900 feet deep. The commencement of the observations, however, has been hitherto delayed.

There is a well at Comb's tannery, near Stowmarket, which was sunk some years ago to the depth of 895 feet, the first 57 feet being clay and sand, and the remainder chalk and marl, except about 20 feet of gault and greensand at the bottom. The proprietor, Lankester Webb, Esq., on being applied to, near the close of last year, at once, in the most obliging manner, undertook to make observations of temperature in it; and a Negretti thermometer was supplied for the purpose.

On proceeding to take the observations, it was found that only the first 283 feet were available, the remaining portion of more than 600 feet being choked with chalky mud. Three sets of observations were taken, with the following results:—

	Temperatures in degrees Fahr.		
	1st set.	2nd set.	3rd set.
3 feet from surface of water	54		
100 „ „ ground	52½	52½	53
150 „ „ „	..	..	53
200 „ „ „	54	54	53
283 „ „ „	52½	54	54

The well is full of water to within 24 feet of the surface of the ground, and is tubed with a 9-inch iron tube for about 90 feet, the top of this tube being about 22 feet below the surface of the ground. The upper portion of the pipe is surrounded by a bricked well, into which there is a drain coming from under two Cornish boilers close to the well; and the water in this bricked well occasionally rises so high as to overflow into the pipe. This is probably the cause of the high temperature recorded at 3 feet below the water-surface. There would appear to be some error in the first observation at 283 feet; and if this be rejected, an increase of about $1\frac{1}{2}$ degree is shown in descending from the depth of 100 feet to that of 283 feet.

The source of the water-supply, which is extremely abundant, is unknown, the only strong spring known to exist in the unchoked portion of the well being in the sand at the depth of only 30 feet. The circumstances are clearly not favourable for deducing any certain inferences regarding the increase of temperature downwards in the neighbouring soil.

The arrangements for further observations of temperature in the Mont-Cenis tunnel are now in the hands of Father Denza, of Moncalieri, near Turin, who wrote to the following effect in April of the present year:—

"Every thing was ready for undertaking the work in the course of last year, when unexpected circumstances over which we had no control obliged us to suspend it. It is now our intention to commence work in the summer on which we are now entering, when I shall determine the temperature, for which observations the instruments are all in order. The thermometrical observations will be made in the interior of the tunnel at various depths, and accompanied by others in the open air on the slope of the mountain according to a fixed plan."

Another Alpine tunnel has been commenced (in the neighbourhood of the St.-Gothard pass), which will be both longer and deeper than that of Mont Cenis. It has been pierced for a distance of about 300 metres at each end—namely, at Geschenen, about 6 miles from Andermatt on the Swiss side, and at Airolo on the Italian side. The engineers at the Geschenen end (which was recently visited by the Secretary) keep a record of the air-temperature in the workings. This is found to be higher by 3° Cent. at the distance now reached than it was in the earlier portion of the tunnel; but no observations of rock-temperature have as yet been made.

Application has recently been made for observations in some of the deepest mines on the continent of Europe; and in three instances a favourable answer has been received. Observations may accordingly be expected from the mines of the Société Cockerill at Seraing, near Liège, from the mines at Anzin in the Département du Nord, and from some of the deepest mines in Bohemia. The Secretary desires to acknowledge his obligations to M. Delesse of the School of Mines at Paris, M. Sadoine of Seraing, M. de Marsilly of Anzin, and Prof. Zenger of Prague.

It is understood that numerous observations have been madeduring the past year with the thermometers sent to Australia. The official report, however, has not been as yet received.

The Committee have learned with pleasure that a series of experiments have been commenced, by Professor Alexander Herschel and Mr. Lebour, on the conductivity of different species of rock—a subject intimately connected with the inquiry in which the Committee are engaged, and one respecting which additional information is greatly needed.

Report on the Rainfall of the British Isles for the years 1872–73, *by a Committee, consisting of* C. Brooke, *F.R.S.* (*Chairman*), J. Glaisher, *F.R.S.*, Prof. J. Phillips, *F.R.S.*, J. F. Bateman, *C.E.*, *F.R.S.*, R. W. Mylne, *C.E.*, *F.R.S.*, T. Hawksley, *C.E.*, Prof. J. C. Adams, *F.R.S.*, Prof. J. J. Sylvester, *F.R.S.*, C. Tomlinson, *F.R.S.*, R. Field, *C.E.*, Dr. Pole, *C.E.*, *F.R.S.*, Prof. D. T. Ansted, *F.R.S.*, A. Buchan, *F.R.S.E.*, G. J. Symons, *Secretary. Drawn up by* G. J. Symons.

Your Committee are glad to be able to report steady progress in the various branches of rainfall work under their supervision. The new stations started in Scotland, as explained in our last Report, have, with few exceptions, been carefully attended to. Your Committee desire to record their thanks to the Directors and Secretary of the Highland and Dingwall and Skye Railways for the very great assistance already afforded, and which your Committee hope to render still more valuable by the personal inspection of the stations by their Secretary at an early date. Gauges have been established at the following stations on these lines, and continuous records have been received from all but those marked with an *.

Dunkeld,	Perth.	Nairn,	Nairn.
Aberfeldy,	,,	Fort George *,	Inverness, E.
Pitlochrie,	,,	Inverness,	,, ,,
Struan,	,,	Beauley *,	,, ,,
Dalnaspidal,	,,	Dingwall,	Ross, E.
Dalwhinnie,	Inverness, E.	Invergordon,	,, ,,
Kingussie,	,, ,,	Tain,	,, ,,
Aviemore,	,, ,,	Bonar Bridge,	,, ,,
Grantown,	Elgin.	Lairg,	Sutherland.
Dava,	Inverness, E.	Golspie,	,,
Forres,	Elgin.	Helmsdale,	,,
Burghead,	,,	Garve *,	Ross, E.
Mulben,	Banff.	Achanault,	,, ,,
Keith,	,,	Achnasheen,	,, W.

Strome Ferry, Ross, W.

Your Committee regret that the vicinity of the Caledonian Canal and the West of Ireland are still very destitute of observers, and that several Welsh counties, *e. g.* Cardigan and Carmarthen, must be added to the list of districts in which observers are especially needed. Your Committee do not, however, enlarge upon this subject on the present occasion, because they hope at an early date to present a revised edition of the list of stations published in the Report of this Association for 1865, and such remarks will be more appropriate then than now. The list published in 1865 has, mainly in consequence of the development of the work under the auspices of the Committee, become obsolete, as it does not contain more than two thirds of the data now collected. The new list will contain all records known at the date of publication, and will be invaluable to future inquirers.

The whole of the forms of inquiry respecting the positions &c. of the rain-gauges in the country were issued last October. Of the 1700 issued, more than half were not returned; and therefore, at their meeting in June of the present year, the Committee instructed their Secretary to send a second application to each of these persons. By this means many more have been obtained. The total number received up to the present time is as follows:—

Div. I.	Middlesex	16	Scotland (*continued*).	Brought up	657
" II.	South-eastern Counties	90	Div. XIII.	South-eastern Counties	12
" III.	South Midland Counties	60	" XIV.	South-western Counties	17
" IV.	Eastern Counties	45	" XV.	West Midland Counties	10
" V.	South-western Counties	103	" XVI.	East Midland Counties	15
" VI.	West Midland Counties	59	" XVII.	North-eastern Counties	23
" VII.	North Midland Counties	44	" XVIII.	North-western Counties	14
" VIII.	North-western Counties	59	" XIX.	Northern Counties	8
" IX.	Yorkshire	60	" XX.	Ireland, Munster	5
" X.	Northern Counties	60	" XXI.	" Leinster	15
" XI.	Monmouth, Wales, and the Isles	45	" XXII.	" Connaught	4
" XII.	Scotland, Southern Counties	16	" XXIII.	" Ulster	18
		657		Total	798

The returns have been sorted, the angular elevations of surrounding objects computed, blank forms prepared; and the tabulation has been commenced on the plan shown by the following specimen (p. 259).

When this tabulation is completed, the information afforded will be of the very highest value; but the labour of discussing the returns (without which they are practically useless) will be very heavy, as may be judged by the fact that the specimen sheet contains only four returns out of the 800 already received.

Although the mass of information thus produced is so large, the Committee cannot but regret that a considerable number of the forms have not been returned, and that it seems probable that those who have neglected to send them back are the persons respecting the positions of whose gauges information may be most desirable. Your Committee therefore feel that there is no alternative but to press forward the personal examination of all these stations as rapidly as possible. It is satisfactory to them to find that the views which they have steadily held of the paramount importance of personal inspection of the stations have not only been recognized and acted upon by the Meteorological Committee of the Royal Society, but have met with great support upon the Continent.

At the Meeting of the French Association for the Advancement of Science at Bordeaux, September 1872, the following resolution was passed:—"We think that rules universally applicable can be laid down for the verification of instruments, and the inspection of meteorological stations, and we believe that it would be one of the greatest advantages which can possibly be realized in meteorology." The same subject was discussed at the Meteorological Conference held at Leipzig in August last, and the following resolution was adopted:—"It is desirable to make a periodical inspection of the stations of each system as frequently as possible." In consequence of the issue of the position-forms previously mentioned, our Secretary has been obliged, both by considerations of time and money, rather to curtail these personal examinations; the number, however, described in the Appendix to the present Report is 54, bringing the total up to 479, to which should be added those tested by Mr. Buchan with the apparatus presented to the Scottish Meteorological Society last year, of which, owing to Mr. Buchan's absence at Vienna, the details have not yet been received.

It will be remembered that the gauges erected in certain parts of Wales, and those erected in East Cumberland and Westmoreland by Mr. Symons in 1865, were transferred to this Committee some years back. As some of the observers have died, and some of the gauges have been disabled, your Committee have directed their Secretary to go over the district, and rearrange them as may seem most expedient.

Specimen of Abstract of Position Returns.

Station. / Observer. / First year of Observation.	Hour of Observation. / Mode of Entry.	Position.	Azimuth and Angular Elevation of surrounding objects.		°	Inclination of Ground.	Top of Gauge above Ground. / Ground above Sea-Level. / As determined by	Pattern of Gauge.	Observer's Remarks.
Teddington, Gomer House. R. D. Blackmore, Esq. 1866.	9 A.M. Preceding.	In a garden of about three acres.	N. N.E. E. S.E. S. S.W. W. N.W.	Tree .... House .... Hedge .... Tree .... Tree .... Wall .... Trees .... Trees	20 25 5 15 15 5 20 15	Level ...	ft. in. 0 10 26 0	XII.	The two nearest trees are weeping ashes, and they cannot intercept any rain. The same gauge has been used throughout, but a new measuring-glass for the last year and a half, of precisely equal capacity, both being used simultaneously, as the old one is still water-tight.
Westminster, Spring Gardens. J. W. Bazalgette. Esq., C.E. 1858.	9 A.M. Preceding.	In garden in front of office, 47 ft. by 69 ft.	N. N.E. E. S.E. S. S.W. W. N.W.	Office frontage. Iron railing ... " " ... " " ... " " ... Wall of terrace Wall of terrace at steps...... Office frontage......	63 0 0 0 0 10 15 	Level ...	6 0 29 0	....	The observations of rainfall were first made in 1858, in the yard at the Office in Greek Street, Soho Square. In 1861 the gauges were removed to the Office in Spring Gardens, where the observations are continued to the present time. No alteration in the position has been made, except from back yard to forecourt or garden in front of Office in 1861.
Westminster, Spring Gardens. J. W. Bazalgette, Esq., C.E. 1858.	9 A.M. Preceding.	On top of roof of office.	W.	Chimney stack.	5	....	65 11 29 0	IV.	Previously to 1861 the gauge was on the top of the Office in Greek Street.
Westminster, Spring Gardens. J. W. Bazalgette, Esq., C.E. 1858.	9 A.M. Preceding.	On top of roof of office.	W.	Chimney stack.	5	....	66 4 29 0	....	Before 1861 the gauge was on the top of the Office in Greek Street.

The experimental gauges erected some years since at Calne, at the expense of Col. Ward, and subsequently removed to Strathfield Turgiss and Hawsker (and of which the results were reduced, presented to this Committee, and by them inserted in their 1869 and 1870 Reports), have been finally dismounted and preserved for future use if required, it being considered that the doubtful points which they were constructed to test have been thoroughly settled.

During the decennial period, extending from 9 A.M. January 1st, 1860, to the same hour on January 1st, 1870, there were 317 records of rainfall kept in the British Isles, without the omission of a single shower. These records therefore give 38,040 monthly values, or 3170 values for each month of the year, and afford by far the most reliable basis for investigation into the seasonal distribution of rainfall ever yet available. Accordingly your Committee have had them all converted into percentages of the yearly totals at the several stations, and tabulated in the same manner as those for previous decades given in our Report for 1868. We give on the present occasion in Table I. the percentages for each individual station, because it has been remarked that we have not given monthly averages, and these percentages afford the means of readily obtaining such averages. It is merely necessary to shift the decimal point two places to the left to convert the percentage into a factor for deducing the monthly amount from the mean annual amount given in the column preceding the monthly percentages. For example, the first station is Shrewsbury, of which the mean annual amount was 19·499, and the January percentage 8·6, which by shifting the decimal point is converted into the factor ·086, and $19{\cdot}499 \times {\cdot}086 = 1{\cdot}677$ in., the computed January fall. The true January mean at Shrewsbury is 1·675 in.; and although the mean, computed by the above method, would not in all cases be in such remarkably close agreement with the true mean, the difference would never be of any consequence.

In Table II. we give the means for each group, and, for comparison, the corresponding values for the previous decade 1850–59, and also the departures of each group from the mean of each district. These values strengthen the evidence which we adduced in our 1868 Report of the greater relative wetness of winter months at western stations, and especially at those of large rainfall. But though they corroborate the fact of the oscillation, they rather reduce its amount. For instance, at western stations in England we have the following monthly percentages for stations at which the average is 20 to 25 in. :—

	1850–59.		1860–69.
January	7·9	January	7·8
July	10·6	July	8·3
Difference	2·7	Difference	0·5

60 to 65 in. :—

January	13·9	January	11·2
July	7·4	July	5·4
Difference	6·5	Difference	5·8

It is satisfactory to find that the general inferences drawn by Mr. Gaster, and quoted in our 1868 Report, are so far corroborated by the fuller information now obtained—that, except as hereinafter noted, we may refer to that Report as giving a fair *résumé* of the facts in the present, always re-

membering that the 1860–69 decade has shown the various features in a less marked degree than the decade 1850–59.

In order to facilitate an accurate determination of the months in which the maximum and minimum rainfall usually occur we have compiled Table III., which gives the months of maximum and minimum respectively for two complete decades (for England, Scotland, and Ireland), adopting the same subdivision into districts, and grouping according to amount of annual fall, as in the previous Tables.

An abstract of the results of Table III. is given as Table IV.

These two Tables are very instructive, and afford information respecting the distribution of the epochs of maximum and minimum previously unattainable.

The general features will be better understood by an examination of the Tables than by any description; and we therefore confine ourselves to remarking that the essential difference between the two decades is that in 1860–69 July, as a month of maximum rainfall, has disappeared altogether, and April has become more frequently that of the minimum. In fact during the last ten years April has been the driest month at most stations in the British Isles, while in the previous decade this distinction was pretty equally shared by February and May.

The gradual retardation of the epochs of maximum and minimum as the annual amount of rainfall increases, is also clearly shown by the upper portion of Table II.; while in the lower or departure portion of Table II. it is very instructive to observe the change of sign as the average total rainfall increases.

With a view to determining whether the same relative monthly values are found at the same station in all decennial periods, we have selected seventeen registers, each extending over at least forty successive years, while four extend over fifty, and one over sixty successive years, and reduced them in the same manner as the 1860–69 values. These are given in Table V.; and the result can hardly be called satisfactory. They show the same general features as the two decades which have been discussed in detail, such as the larger percentages in winter months in wet districts, and in the summer and early autumn in dry districts; but the months of maximum and minimum shift about to an extent which would not be expected, considering that each value represents the average of ten years. An examination of these records, all embracing more than one third of a century, proves that, however steady the ten-yearly average *amount* of rain may be, its distribution over the months is not so by any means; so that, as far as our present investigations go, it is impossible to lay down any general law as to the precise month of maximum and minimum fall.

It has been the custom of this Committee to follow the practice inaugurated by Mr. Symons before their appointment, and give biennially details of the monthly fall of rain over the British Isles. As this practice has several advantages, your Committee are unwilling to depart from it, and therefore leave the detailed discussion of the rainfall of 1872 until next year; at the same time, as the total was in many districts excessive, and in several localities unprecedented, they have instructed their Secretary to prepare for the Bradford Meeting a map showing the more remarkable general features, and briefly to explain it. But as the subject will be discussed at length next year, they do not make either the map or remarks a part of the present Report.

TABLE I.—Monthly Average Percentage at each Station during the decade 1860–69.

ENGLAND AND WALES.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Monthly percentage of Annual Fall.											
			Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
in. in.	*Western District.*	in.												
15–20......	Shrewsbury	*19·499	8·6	6·5	7·7	4·8	8·4	11·3	4·8	10·9	12·8	9·8	5·9	8·5
20–25...	Holbeck	22·853	9·5	7·0	7·8	5·5	7·1	7·0	8·6	9·4	9·9	9·9	8·1	10·2
	Leventhorpe Hall	23·261	6·6	6·6	7·3	6·4	8·5	7·8	8·7	10·1	10·1	10·0	8·3	9·6
	Tickhill.......	23·990	7·7	5·8	7·5	5·7	8·0	8·2	9·5	10·4	10·2	10·4	7·8	8·8
	Maes-y-dre	24·430	7·1	5·1	6·4	5·9	7·6	7·4	7·8	10·0	10·8	12·3	9·4	10·2
	York..............................	24·479	7·2	6·2	7·4	6·0	8·1	8·2	7·6	11·4	11·0	9·3	7·8	9·8
	Haughton Hall	24·870	8·6	5·3	7·7	5·3	9·3	9·8	7·4	11·5	10·3	8·8	7·0	7·7
	Mean of 6 Stations	23·981	7·8	6·0	7·3	5·8	8·1	8·1	8·3	10·4	10·4	10·1	8·1	9·6
25–30...	Hawarden..........................	26·443	8·0	5·9	8·0	5·8	8·6	7·1	6·8	9·9	10·1	10·6	9·1	10·1
	Burford	26·744	8·6	7·6	7·3	5·7	8·4	9·3	6·9	7·9	10·9	10·8	6·8	9·8
	Leominster	27·105	10·1	6·3	7·7	5·8	8·5	8·5	7·1	8·9	11·0	10·0	7·0	9·1
	Quedgeley.........................	27·421	11·3	6·4	7·5	5·0	7·7	9·1	6·9	8·5	10·9	9·8	7·6	9·3
	Sheffield	28·159	9·5	7·6	8·0	7·0	8·0	7·7	6·7	8·2	9·5	11·0	7·7	9·1
	Ross	28·211	11·6	6·1	8·0	5·3	7·9	8·0	6·2	8·5	11·2	9·8	7·4	10·0
	Knowbury	28·530	7·9	6·2	7·0	6·3	10·4	9·0	7·2	9·5	11·6	8·8	6·8	9·3
	Long Sutton.......................	28·574	10·7	6·2	8·2	5·4	7·5	9·5	6·5	8·9	9·9	10·6	7·7	8·9
	Swindon	28·592	10·5	6·6	7·7	5·8	8·7	10·2	6·6	8·9	10·0	9·2	7·7	8·1
	Alderney	28·624	11·3	7·2	9·2	4·8	7·7	6·1	4·4	7·3	9·6	11·5	9·4	11·5
	Chiltern...	29·279	10·8	6·8	8·0	5·7	7·9	8·5	5·8	8·8	10·4	10·4	7·2	9·7
	Mean of 11 Stations	27·971	10·0	6·6	7·9	5·7	8·3	8·4	6·5	8·7	10·5	10·2	7·7	9·5

30–35...	Baverstock	30.247	11.1	6.4	8.4	5.2	8.1	8.3	5.7	8.2	11.1	10.1	7.8	9.6
	Bristol, Small Street	30.549	11.7	6.9	7.3	5.0	7.2	8.3	6.2	10.7	9.7	10.0	8.0	9.0
	Penistone	30.570	9.0	7.4	8.5	5.6	8.0	8.6	6.8	7.9	9.1	11.8	8.0	9.3
	Point of Ayre	30.609	10.4	7.3	9.1	5.1	6.5	5.7	6.3	9.7	8.4	11.0	9.6	10.9
	Llandudno	31.004	9.8	6.3	7.1	5.2	7.1	6.1	6.9	9.8	9.6	11.7	10.0	10.4
	Aske	31.105	9.0	7.5	8.4	5.8	6.8	7.8	6.7	9.1	9.5	11.0	8.8	9.6
	Broomhall Park	31.276	9.0	7.5	8.5	6.3	7.7	8.3	6.4	8.4	9.4	10.6	7.9	10.0
	Newton	31.633	7.6	6.7	6.7	5.6	7.2	9.0	8.0	10.5	10.9	10.8	8.5	8.5
	Exeter Institution	31.757	11.8	6.6	10.2	5.0	8.0	6.5	5.1	7.3	9.3	10.6	8.4	11.2
	Bosley Reservoir	32.043	7.3	6.1	7.5	5.1	7.1	8.6	7.9	10.8	11.1	10.5	9.1	8.9
	Rastrick	32.121	9.5	7.3	7.9	5.9	7.3	7.7	7.6	8.2	10.1	11.0	8.1	9.4
	Bridport	32.248	11.5	7.3	8.3	5.1	7.0	7.3	5.8	7.8	9.5	10.7	8.5	11.2
	Manchester, Ardwick	32.597	7.3	6.9	7.1	5.0	6.5	7.9	7.6	10.1	11.6	10.8	9.1	10.1
	Further Barton	32.612	11.5	6.5	7.6	5.2	7.1	8.6	6.9	9.1	10.8	9.6	7.6	9.5
	Clyst Hydon	32.694	11.6	6.6	9.8	5.2	7.4	6.6	5.8	7.3	10.7	9.8	8.5	10.7
	Bosley Minns	32.849	7.3	5.3	6.4	5.3	7.6	8.0	8.5	11.1	10.6	11.4	8.8	9.7
	Bristol Institute	32.955	11.9	7.4	7.4	5.3	6.9	7.8	6.4	10.3	9.5	10.2	8.1	8.8
	Denton Reservoir	32.974	7.3	6.3	7.0	5.5	7.4	8.4	8.3	9.7	11.0	10.8	8.8	9.5
	South Shore	32.994	9.0	7.1	7.1	4.9	7.1	5.9	6.3	9.7	10.1	12.4	10.2	10.2
	Well Head	33.313	8.8	9.2	8.4	5.2	7.1	5.6	6.8	8.6	10.0	10.8	9.2	10.3
	Rocklands	33.591	12.9	6.5	8.5	5.0	6.6	7.6	6.1	7.9	11.2	9.2	8.0	10.5
	Gorton Reservoir	33.712	7.3	6.3	7.1	5.3	7.2	8.3	8.5	9.9	11.2	10.8	8.8	9.3
	Godley Reservoir	33.979	7.2	6.4	7.2	5.6	7.3	8.6	8.2	10.1	11.0	10.7	8.5	9.2
	Longwood Reservoir	34.008	8.8	8.1	8.6	5.6	6.9	7.2	7.1	8.1	10.4	10.5	9.0	9.7
	Clifton	34.085	11.4	6.8	7.3	5.2	7.4	8.5	6.4	10.5	9.7	9.9	7.9	9.0
	Macclesfield, M. S. & L. R.	34.536	7.1	6.1	7.6	5.3	7.4	8.3	8.3	10.5	11.1	9.8	8.9	9.6
	Broadhembury	34.562	10.6	6.8	9.0	5.2	7.5	7.3	6.4	8.1	10.5	10.4	8.2	10.0
	Old Trafford	34.727	7.8	7.0	7.1	5.4	6.6	7.8	7.6	9.4	11.6	10.6	9.3	9.8
	Marple Aqueduct	34.810	7.3	6.2	7.9	5.4	7.5	8.2	8.3	9.7	11.0	11.0	8.6	8.9
	Rufford	34.999	8.6	6.0	7.2	5.0	6.9	7.7	7.0	9.9	10.8	12.2	9.4	9.3
	Mean of 30 Stations	32.699	9.4	6.8	7.9	5.3	7.2	7.7	7.0	9.3	10.3	10.7	8.7	9.7

* The height of each gauge above ground and sea-level was given in the Report for 1871.

TABLE I. (*continued*).

ENGLAND AND WALES.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Monthly percentage of Annual Fall.											
			Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Western District (continued).	in.												
in. in. 35–40...	Marple Top Lock	35·254	8·2	6·2	6·9	5·5	7·3	8·1	8·0	9·6	10·7	11·2	8·8	9·5
	Hengoed	35·647	10·9	6·5	8·4	5·4	9·3	7·7	5·4	9·0	9·5	10·1	7·7	10·1
	Appleby	35·994	11·7	8·0	6·9	5·4	5·9	6·7	6·4	9·2	10·0	9·7	8·5	11·6
	Strines Dale	36·007	7·5	6·0	6·8	5·2	7·9	8·5	8·3	9·9	11·1	11·1	8·8	8·9
	Waterhouses	36·133	7·8	7·0	7·8	5·0	7·5	7·4	7·6	9·7	11·2	10·5	8·9	9·6
	Macclesfield, Park Green	36·746	7·3	6·6	8·4	6·1	6·4	8·8	7·6	10·5	10·4	9·9	8·2	9·8
	Manchester, Piccadilly	36·775	7·9	6·8	7·1	5·0	6·7	8·2	7·6	9·5	11·7	10·8	8·9	9·8
	Oldham	37·123	8·3	7·1	7·1	5·2	7·1	7·7	7·2	9·6	11·1	10·9	9·4	9·3
	Guernsey	37·177	12·3	7·1	9·4	4·7	7·0	5·2	4·6	7·0	9·7	10·7	11·5	10·8
	Arnfield Reservoir	37·232	7·4	7·1	7·2	5·6	6·6	8·3	8·4	9·9	10·6	10·6	9·2	9·1
	Sponds Hill	37·464	8·0	5·5	7·9	6·2	7·6	7·9	9·1	10·1	9·9	10·6	8·3	8·9
	Mottram	37·732	7·4	7·0	7·4	5·8	7·2	7·9	8·4	9·5	10·6	10·6	8·8	9·4
	Helstone	37·872	11·4	7·7	8·6	5·6	6·6	5·9	5·9	7·4	8·9	10·4	10·2	11·4
	Bradninch	38·060	11·8	7·6	9·5	5·2	7·0	6·5	6·3	7·7	9·4	9·7	8·6	10·7
	Howick House	38·303	9·2	7·0	7·1	5·1	7·2	6·8	6·7	9·9	9·9	12·0	9·1	10·0
	Treharrock House	39·301	10·9	7·1	7·0	4·5	6·2	6·9	6·6	9·0	9·5	11·8	9·7	10·8
	Redmires	39·684	7·7	8·3	8·8	6·9	7·0	8·0	6·4	8·8	9·1	10·4	8·6	10·0
	Barnstaple	39·905	10·8	6·8	7·4	5·4	6·3	7·3	6·2	9·4	10·4	11·1	9·1	9·8
	Mean of 18 Stations	37·356	9·3	7·0	7·8	5·4	7·0	7·4	7·0	9·2	10·2	10·7	9·0	10·0

40–45...	Fairfield	40.898	8.0	6.6	7.3	5.2	7.1	7.7	7.5	9.8	10.9	10.9	9.3	9.7
	Tehidy Park	41.229	13.6	7.6	7.8	4.7	6.4	6.1	5.6	6.6	8.8	10.7	10.0	12.1
	Settle	41.349	11.5	9.5	7.3	5.4	5.8	5.6	5.8	8.7	9.9	9.9	10.3	10.3
	Penzance	41.507	13.4	8.5	8.1	5.1	5.8	5.3	5.8	7.0	8.3	10.1	10.5	12.1
	Saddleworth	41.968	7.7	7.9	6.4	5.5	7.7	8.4	7.4	9.4	10.8	10.8	8.9	9.1
	Cardiff, W. W. Ely	42.016	10.4	6.6	6.8	5.1	6.4	7.9	6.2	9.1	11.4	12.4	8.8	8.9
	Sherborne Reservoir	42.097	11.7	7.9	7.5	5.4	6.8	7.4	7.0	8.3	9.4	10.6	7.9	10.1
	Penarth	42.556	13.1	7.4	8.1	4.8	6.5	6.4	5.7	6.6	8.9	10.3	10.0	12.2
	Truro	42.877	13.0	7.4	7.8	4.8	6.5	6.3	5.6	6.8	8.8	10.8	10.0	12.2
	Ham	42.888	12.7	7.6	8.3	4.8	6.7	6.1	6.0	7.4	9.3	10.5	9.0	11.6
	Bovey Tracey	43.126	13.7	7.3	10.0	4.6	7.5	6.1	4.9	6.4	9.5	9.7	8.8	11.5
	Tavistock	43.356	12.1	7.2	7.7	4.5	6.3	6.4	5.6	8.4	10.3	10.3	9.1	12.1
	Whaley	43.894	7.9	6.7	8.8	6.3	6.9	7.8	8.7	9.4	9.1	10.1	8.9	9.4
	Caton	43.944	9.2	7.2	7.5	5.0	6.3	7.8	5.8	11.1	10.1	10.8	9.3	9.9
	Nagden Dane	44.132	7.5	7.1	6.2	4.7	5.7	7.3	7.5	9.9	11.1	12.3	10.2	10.5
	Heaton	44.210	7.1	6.7	6.9	5.7	6.7	7.6	7.1	10.1	11.7	11.2	9.2	10.0
	Downham Hall	44.786	9.1	9.0	6.5	5.5	6.3	6.9	6.5	9.1	9.8	10.2	10.5	10.6
	Saltram Gardens	44.813	12.4	6.8	8.2	5.2	7.1	6.4	6.3	7.6	9.7	10.8	9.0	10.5
	Cefnfaes	44.980	11.3	8.0	8.2	5.4	6.4	6.5	5.8	8.7	9.9	10.8	9.3	9.7
	Mean of 19 Stations	42.980	10.8	7.5	7.6	5.1	6.6	6.8	6.4	8.5	9.9	10.7	9.4	10.7
45–50...	Lampeter	45.183	11.9	7.0	7.5	4.7	5.9	6.3	7.5	6.9	11.6	10.7	9.2	10.8
	Holker	45.625	9.7	7.6	7.5	4.9	6.3	6.0	5.8	10.4	10.2	11.3	9.5	10.8
	Coryton Lew Down	45.941	12.7	6.9	8.4	4.7	5.8	6.4	5.9	8.0	10.1	10.2	8.7	12.2
	Ovenden Moor	46.090	9.1	8.8	7.4	6.0	6.5	7.1	5.7	8.5	10.2	10.9	9.5	10.3
	Rhodes Wood Reservoir	46.323	7.8	8.0	7.8	5.6	6.5	7.4	7.5	9.6	10.1	10.4	9.6	9.7
	Warley Moor	46.330	8.8	8.9	7.3	6.2	6.3	6.7	6.0	8.5	10.4	11.0	9.4	10.5
	Castle Hill	47.118	10.2	6.7	7.8	5.1	6.2	7.3	6.8	9.6	10.6	11.0	8.9	9.8
	Bodmin	47.708	13.0	6.8	8.0	4.7	6.3	6.2	5.8	7.5	9.3	10.9	9.9	11.6
	Stonyhurst	48.560	8.3	8.0	7.4	5.2	6.3	6.8	6.6	9.9	10.5	10.5	10.7	9.8
	Ridgeway	48.646	12.6	7.1	8.6	4.9	6.7	6.2	5.8	7.7	10.0	10.8	8.4	11.2
	Bolton-le-Moors	48.981	8.4	6.9	7.4	4.9	6.0	6.9	6.5	10.6	11.1	11.5	9.9	9.9
	Haverfordwest	49.441	12.2	7.5	7.7	5.3	6.0	5.7	5.5	8.8	9.7	10.5	10.2	10.9
	Mean of 12 Stations	47.162	10.4	7.5	7.7	5.2	6.2	6.6	6.3	8.9	10.3	10.8	9.5	10.6

TABLE I. (*continued*).

ENGLAND AND WALES.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Monthly percentage of Annual Fall. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Western District (continued).	in.												
in. in. 50–55...	Midgley Moor	50·000	8·9	8·8	7·5	6·1	6·1	6·6	5·8	8·5	10·7	10·9	9·5	10·6
	Combs Reservoir	50·008	9·1	7·2	8·6	5·4	5·9	7·6	7·5	9·2	9·2	10·1	10·1	10·1
	Woodhead Reservoir	51·828	8·0	8·4	8·3	5·5	6·5	7·3	7·1	8·9	9·8	10·4	9·7	10·1
	Tavistock, West Street	53·170	12·9	7·2	7·8	4·5	6·4	6·6	5·9	8 0	10·1	10·1	9·2	11·3
	Kendal	53·322	10·9	9·0	7·5	5·5	5·5	6·1	5·3	9·6	10·5	10·1	9·4	10·6
	Standedge	53·700	8·1	8·3	7·4	5·4	7·2	7·6	7·0	9·0	11·6	10·1	9·1	9·2
	Mire House	53·756	11 0	8·7	7·7	5·4	5·9	5·6	5·1	8·2	10·1	10·6	10 6	11·1
	Warleggan	54·557	12·5	6·6	7·8	4·7	6·4	6·4	6·4	8·0	9·4	11·0	9·0	11·8
	Mean of 8 Stations	52·543	10·2	8·0	7·8	5·3	6·2	6·7	6·3	8·7	10·2	10·4	9·6	10·6
55–60...	Dunford Bridge	56·177	8·8	8·7	8·4	6·0	6·5	6·5	6·3	7·9	9·1	11·5	9·8	10·5
	Belmont	56·610	7·7	7·2	6·9	5·0	6·1	7·3	6·8	10·5	11·5	10·9	9·9	10·2
	Whinfell Hall	57·366	10·9	8·1	7·4	5·3	5·8	6·0	5·1	8·7	10·2	11·2	10·1	11·2
	Watermillock	59·910	12 5	9·8	7 6	5·1	5·0	5·0	4 9	7·7	9·7	10·0	10·2	12·5
	Mean of 4 Stations	57·516	10·0	8·5	7·6	5·3	5·8	6·2	5·8	8·7	10·1	10·9	10·0	11·1
60–65......	Arncliffe	60·075	11·2	8·8	7·7	6·0	5·2	5·6	5·4	8·9	10·3	10·0	10·8	10·1

150–155...	Seathwaite	154.046	11.1	9.6	8.6	5.4	5.0	5.4	5.3	8.3	9.3	9.7	10.3	12.0
	Central District.													
15–20.....	Cardington	18.170	9.4	6.0	7.3	5.4	8.3	9.5	7.5	10.8	10.4	9.8	7.8	7.8
	Southwell	20.844	7.1	6.4	8.0	5.3	9.5	8.5	8.0	10.1	11.2	10.4	6.5	9.0
	Cardington	21.760	9.7	6.3	8.4	5.7	8.6	9.6	7.5	10.1	9.7	9.4	7.6	7.4
	Worksop	22.469	7.0	7.1	7.6	5.5	9.1	8.8	8.3	10.6	9.0	11.5	7.2	8.3
	Cardington	22.487	9.6	6.4	8.3	6.0	8.6	9.2	7.6	10.0	9.8	9.4	7.6	7.5
	Retford	22.743	7.1	5.4	7.4	5.4	10.4	8.3	8.4	10.9	10.3	10.3	7.6	8.5
20–25...	Althorpe	23.349	9.4	6.2	7.6	5.5	8.6	9.6	7.8	10.1	10.6	8.4	8.0	8.2
	Wellingborough	24.092	9.6	7.3	8.4	5.8	8.5	9.0	8.1	9.5	9.7	8.8	7.3	8.0
	Waltham Rectory	24.319	7.6	6.2	8.3	5.2	9.1	8.9	8.5	10.3	10.2	9.1	7.6	9.0
	Belvoir Castle	24.476	8.3	5.9	8.5	6.1	8.3	8.5	7.8	10.8	10.0	9.4	7.4	9.0
	Norwood	24.591	8.1	6.3	8.2	6.2	8.7	8.1	8.2	9.3	9.8	10.9	7.0	9.2
	Welbeck	24.636	7.0	5.6	7.7	5.5	10.2	8.6	8.2	11.6	10.7	10.3	7.1	7.5
	Mean of 11 Stations	23.251	8.2	6.3	8.0	5.7	9.1	8.8	8.0	10.3	10.1	9.8	7.4	8.3
	Wigston Grange	25.165	8.6	6.2	8.5	6.0	8.4	9.2	7.2	9.9	10.2	9.5	7.6	8.7
	London, Camden Square	25.681	9.9	6.2	7.8	5.3	9.3	9.9	6.9	9.3	9.8	9.3	8.1	8.2
	High Wycomb	25.705	10.8	6.4	8.0	5.6	7.8	8.9	8.2	8.4	10.2	9.1	7.9	8.7
	Englefield	25.726	10.1	5.9	8.2	5.6	8.3	9.9	6.6	9.0	10.4	10.3	7.1	8.6
	Radcliffe Observatory	26.129	9.9	6.0	7.8	5.7	8.0	9.9	8.4	8.7	10.8	9.3	7.8	7.7
	Banbury	26.222	9.6	6.3	8.1	5.2	9.1	9.9	6.7	9.0	10.9	8.9	7.4	8.9
25–30...	Derby	26.807	7.5	6.5	7.9	6.0	8.1	9.5	6.9	11.4	10.7	10.2	6.3	9.0
	Chesterfield	26.930	8.8	7.2	8.1	6.3	8.5	8.4	6.6	9.1	9.8	11.0	7.0	9.2
	Aldershot	27.036	11.1	6.7	8.2	5.7	7.5	8.2	7.0	9.0	10.1	9.5	8.2	8.8
	Long Wittenham	27.379	10.7	5.9	7.8	5.8	7.7	10.2	7.8	9.1	9.4	10.3	7.3	8.0
	Wolverhampton	27.917	8.2	6.1	7.5	5.0	8.9	9.5	7.1	10.9	11.1	9.1	7.9	8.7
	Northwick Park	28.017	9.9	7.2	8.7	6.0	7.4	9.2	7.3	6.6	10.4	10.2	8.6	8.5
	Worcester, Lark Hill	28.039	9.3	6.1	7.4	5.3	9.5	9.6	7.4	9.0	11.1	9.1	7.0	9.2
	Southampton, O. S. O.	28.293	11.1	6.7	7.5	5.2	8.0	8.5	7.3	7.8	10.3	10.3	7.5	9.8
	Mean of 14 Stations	26.789	9.7	6.4	8.0	5.6	8.3	9.3	7.2	9.1	10.4	9.7	7.6	8.7

Table I. (*continued*).

England and Wales.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Monthly percentage of Annual Fall.											
			Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Central District (continued).	in.												
in. in. 30–35...	Birmingham, Calthorpe Street..	30·562	9·7	6·3	8·8	5·3	7·8	9·1	6·9	10·1	10·5	9·3	7·3	8·9
	Osborne	30·725	10·8	6·6	7·4	4·4	7·6	7·4	5·7	7·7	12·9	11·2	8·5	9·8
	Orleton	30·900	9·6	6·4	7·8	5·6	8·2	9·6	6·9	9·1	10·7	9·5	7·1	9·5
	Fareham	33·906	10·3	6·9	8·1	4·8	7·5	8·2	6·4	8·3	10·3	11·2	8·3	9·7
	Selborne	34·427	11·7	6·9	7·4	5·1	7·1	7·7	6·4	8·6	10·1	10·5	8·5	10·0
	Mean of 5 Stations	32·104	10·4	6·6	7·9	5·1	7·6	8·4	6·5	8·8	10·9	10·3	7·9	9·6
40–45......	Chapel-en-le-Frith	41·947	8·4	6·9	8·1	5·8	6·1	7·9	6·9	9·5	10·0	10·8	9·2	10·4
45–50......	Combs Moss......................	49·620	8·6	6·2	6·4	6·0	6·7	8·7	7·2	9·7	9·5	11·3	10·1	9·6
50–55......	Woodhead........................	52·188	8·8	8·3	8·0	6·0	6·8	7·6	6·8	8·7	9·8	10·3	9·8	9·1
	Eastern District.													
15–20......	Hunstanton	19·559	5·5	5·2	7·6	4·9	8·4	7·3	8·9	11·8	10·3	10·4	10·6	9·1

20–25...	Bishopwearmouth	20·247	7·3	4·9	7·4	5·3	8·6	8·4	10·1	10·3	10·3	10·2	8·6	8·6
	Dorwards Hall	20·466	9·2	6·2	8·9	5·3	8·9	9·4	7·7	9·2	8·9	9·4	8·6	8·3
	Stretham	20·609	7·7	5·5	8·3	4·9	9·2	8·6	10·2	10·7	10·1	8·9	7·9	8·0
	Lincoln	20·870	6·7	5·6	7·4	6·1	9·4	9·6	7·8	10·8	10·0	9·7	7·9	9·0
	Stockwith	21·347	7·6	5·4	6·7	5·6	9·6	9·0	8·4	11·8	10·0	9·7	7·9	8·3
	Grimsby	21·391	7·6	6·0	7·8	5·3	7·1	8·8	7·2	10·5	11·1	9·0	10·2	9·4
	Gainsborough	21·659	6·5	4·9	6·1	5·3	8·9	9·0	8·8	13·4	11·0	9·2	7·7	9·2
	Barnetby	22·163	7·8	5·7	7·1	5·7	7·9	8·7	7·6	10·8	11·6	9·0	8·6	9·5
	Norwich	22·169	8·4	7·4	9·3	5·2	8·3	8·2	8·8	7·3	8·5	9·1	9·8	9·7
	Dickleborough	22·223	7·9	7·4	9·7	4·3	7·9	8·5	8·7	8·7	8·7	9·6	9·3	9·3
	Grantham	22·407	8·7	6·0	9·2	5·5	8·6	7·8	8·4	9·8	9·3	9·4	7·8	9·5
	Outwell	22·637	7·0	5·6	7·0	5·0	9·8	9·3	9·6	10·7	10·4	9·5	8·4	7·7
	New Holland	22·665	7·9	5·9	7·6	5·7	7·6	9·1	7·1	11·0	9·9	9·2	9·1	9·9
	Dunmow	22·750	8·6	6·5	7·8	5·1	9·4	9·3	6·9	10·3	9·1	9·5	8·9	8·6
	Ashdon Rectory	23·056	9·5	7·1	7·8	5·5	8·8	8·2	7·7	10·4	9·2	9·3	8·4	8·1
	Hamerton	23·132	8·0	5·5	8·0	6·3	9·7	9·0	8·9	9·1	10·1	9·4	8·0	8·0
	Fincham Rectory	23·139	7·4	6·2	8·2	5·1	9·4	8·7	8·6	10·1	10·1	9·2	7·9	9·1
	Holkham	23·232	8·4	7·2	8·6	5·5	8·3	7·0	8·6	9·5	8·6	9·1	9·8	9·4
	Kew Observatory	23·282	9·6	5·9	7·6	5·5	8·6	10·6	7·5	10·1	10·4	9·3	7·7	7·2
	Market Rasen	23·429	8·5	6·7	7·5	5·2	8·6	9·4	7·0	9·9	10·9	9·1	9·4	7·8
	Wimbledon	23·476	8·5	5·9	7·3	5·4	9·3	10·5	7·9	10·0	9·7	9·7	8·4	7·4
	Westley	23·522	8·6	7·1	8·0	5·4	8·4	8·6	9·1	9·6	8·3	9·5	8·9	8·5
	Royston	23·569	10·0	6·4	8·4	5·6	9·2	8·0	7·2	10·3	9·3	9·1	8·3	8·2
	Holkham	23·875	9·0	7·1	8·7	5·4	8·0	6·9	8·6	9·3	8·5	8·9	9·9	9·7
	Hitchen	23·922	10·5	6·6	8·2	5·5	8·2	8·7	8·0	10·4	9·0	9·4	7·7	7·8
	Bury St Edmunds	23·962	8·5	7·1	7·6	5·5	8·3	9·1	9·9	8·6	8·8	9·9	8·1	8·6
	Honingham	23·975	7·7	7·3	9·3	4·8	8·4	7·7	8·6	8·5	8·9	10·0	9·2	9·6
	Fennes	23·984	9·3	7·4	8·0	5·6	8·7	8·5	7·2	10·2	9·3	9·1	8·6	8·1
	Wisbeach, North Brink	24·037	8·8	6·0	7·7	5·5	8·4	9·3	8·2	10·0	9·4	8·7	8·5	9·5
	Appleby Vicarage	24·097	8·5	5·6	7·3	5·5	8·1	8·5	8·1	11·2	9·7	9·8	8·4	9·3
	Brigg	24·118	7·8	5·9	6·8	5·2	8·1	8·4	8·4	10·4	11·1	9·4	8·7	9·8
	Epping	24·132	8·9	6·2	7·4	5·3	9·4	10·6	6·8	10·0	10·3	9·3	7·7	8·1
	Croydon, Waldronhurst	24·388	9·2	6·1	7·4	5·4	9·0	9·6	7·7	9·6	9·6	10·8	8·0	7·6
	Culford	24·835	8·5	7·3	8·0	5·0	8·5	9·0	7·8	9·5	8·3	10·0	8·8	9·3
	Mean of 34 Stations	22·905	8·3	6·3	7·9	5·4	8·7	8·8	8·2	10·1	9·6	9·4	8·6	8·7

TABLE I. (*continued*).

ENGLAND AND WALES.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
			Monthly percentage of Annual Fall.											
	Eastern District (continued).	in.												
in. in. 25–30...	Bayfordbury	25·011	10·4	6·7	7·8	5·6	8·3	8·7	7·2	9·2	9·6	9·1	8·7	8·7
	Hull	25·024	8·3	5·5	7·7	5·5	7·4	8·0	7·2	10·9	10·4	9·5	9·0	10·6
	Weybridge Heath	25·051	10·0	6·6	7·5	5·4	8·1	9·5	7·4	9·4	10·4	9·4	8·4	7·9
	Egmere	25·097	7·3	7·3	8·5	6·1	7·7	6·9	8·5	9·3	9·8	8·8	9·6	10·2
	Aldham	25·469	9·1	6·7	8·2	5·3	8·9	9·0	7·7	9·8	8·4	9·6	8·7	8·6
	Hunton Court	25·998	10·2	6·7	8·5	5·1	8·7	8·1	6·8	7·7	9·8	10·1	9·7	8·6
	North Shields	26·065	8·5	5·7	7·9	6·2	8·8	8·2	7·3	9·9	8·5	10·4	9·4	9·2
	Croydon, Tanfield Lodge	26·333	9·7	7·0	7·9	5·3	8·2	9·2	7·7	8·7	9·8	10·0	8·6	7·9
	High Wickham	26·373	10·1	5·8	7·5	5·2	8·4	6·5	6·8	8·5	10·3	11·8	9·8	9·3
	Nash Mills	26·388	10·9	6·0	7·7	5·5	8·6	9·4	7·0	9·8	9·9	8·9	7·9	8·4
	Wallsend	26·640	8·9	6·4	8·2	6·7	8·3	7·5	7·7	9·3	8·1	10·8	8·9	9·2
	West Thorney Island	26·875	10·6	6·0	7·8	4·8	7·1	8·2	6·5	8·3	11·0	11·8	8·5	9·4
	Wylam	26·900	8·8	6·3	8·8	6·6	8·2	7·2	7·2	8·9	9·0	11·6	9·1	8·3
	Malton	27·455	8·0	5·9	7·9	6·1	8·0	7·8	8·5	9·5	9·7	9·7	8·8	10·1
	Linton Park	27·559	9·4	7·1	9·0	4·9	8·1	8·0	7·3	8·5	9·3	10·0	9·5	8·9
	Cow Roast	27·594	11·1	6·7	7·9	5·4	8·4	8·5	7·0	8·7	10·8	8·8	8·3	8·4
	Stamfordham	27·637	9·8	6·4	7·5	6·5	7·5	7·5	8·7	9·2	10·1	10·5	8·9	7·4
	Gorhambury	27·849	11·1	6·2	7·7	5·6	8·2	9·8	6·8	9·5	9·3	9·1	8·2	8·5
	Tunbridge	28·258	9·7	7·1	8·4	5·2	7·5	8·4	7·8	8·2	9·6	10·1	9·3	8·7
	Shotley Hall	28·494	8·8	6·6	9·4	6·6	7·2	7·7	7·7	8·7	8·4	10·8	9·1	9·0
	Lilburn Tower	28·657	8·9	5·6	7·7	5·5	7·0	6·5	8·3	9·8	8·4	12·7	10·4	9·2
	Bywell	28·874	9·7	6·3	9·1	6·6	7·9	7·4	7·0	8·9	8·4	11·0	8·6	9·1
	Chichester	29·026	10·5	5·8	7·8	4·2	7·5	7·4	7·0	8·0	11·4	12·5	8·5	9·4
	Shopwyke	29·194	10·3	5·6	7·7	4·0	7·6	7·1	7·2	7·8	11·2	12·4	8·8	10·3
	Berkhampstead	29·284	11·2	6·5	7·9	5·8	7·7	9·3	6·6	9·3	10·3	8·8	8·0	8·6
	Darlington	29·519	9·0	5·9	9·1	5·6	7·9	7·3	8·4	10·2	9·4	8·9	7·5	10·8
	Mean of 26 Stations	27·178	9·6	6·3	8·1	5·6	8·0	8·0	7·4	9·1	9·7	10·3	8·8	9·0

30–35...	Birmingham, Calthorpe Street.	30·562	9·7	6·3	8·8	5·3	7·8	9·1	6·9	10·1	10·5	9·3	7·3	8·9
	Maresfield, Forest Lodge	31·479	10·4	6·9	7·2	4·4	6·7	7·3	7·5	8·2	10·4	12·1	9·2	9·7
	,, Rectory	32·199	10·8	5·8	7·6	4·3	7·1	6·9	7·7	8·3	10·0	12·2	9·8	9·5
	Horton Park........................	32·677	9·1	6·6	8·6	4·5	8·2	6·4	6·5	9·3	10·1	10·0	10·7	10·0
	Chilgrove	33·224	10·5	6·3	6·8	4·1	7·3	8·2	6·9	8·9	11·6	11·1	8·2	10·1
	Parkend	33·550	11·9	10·7	6·8	5·7	6·3	7·4	6·6	7·3	8·7	9·7	9·2	9·7
	Dale Park..........................	33·732	10·5	5·5	7·3	4·0	7·8	7·7	7·1	8·7	11·1	13·4	7·5	9·4
	Mean of 7 Stations.........	32·489	10·4	6·9	7·6	4·6	7·3	7·6	7·0	8·7	10·4	11·1	8·8	9·6
35–40...	Westdean	37·082	10·6	6·2	7·8	4·2	7·2	7·5	6.2	8·8	11·2	11·9	8·3	10·1
	Liss	38·033	12·0	7·1	7·8	4·7	6·8	7·2	6·1	7·8	10·2	11·1	9·3	9·9
	Mean of 2 Stations	37·558	11·3	6·7	7·8	4·4	7·0	7·4	6·1	8·3	10·7	11·5	8·8	10·0
50–55...	Allenheads	51·160	11·6	9·5	8·7	6·2	5·8	7·5	5·5	5·6	8·5	10·8	9·9	10·4

SCOTLAND.

	Western District.													
25–30...	Sumburghead	26·454	11·8	7·7	6·5	6·2	5·9	4·2	5·6	9·8	9·2	11·2	10·0	11·9
	Little Ross	26·981	11·2	7·4	7·1	5·5	8·0	6·0	5·6	8·7	9·1	11·7	9·0	10·7
	Mull of Galloway..................	27·656	12·8	6·9	8·4	5·5	6·6	5·6	5·8	8·5	9·5	10·5	10·6	9·3
	Bothwell Castle	28·885	11·4	8·8	7·3	5·8	6·7	6·8	8·3	8·6	8·2	10·4	7·7	10·0
	Mean of 4 Stations	27·494	11·8	7·7	7·3	5·8	6·8	5·6	6·3	8·9	9·0	11·0	9·3	10·5

TABLE I. (*continued*).

SCOTLAND.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
			Monthly percentage of Annual Fall.											
	Western District (continued).	in.												
in. in. 30–35...	Island Glass	31·129	8·7	10·0	7·3	5·7	5·5	5·9	5·8	11·1	10·5	9·8	9·7	10·0
	Barrahead	31·726	12·3	7·7	8·1	4·3	5·9	6·6	5·7	10·6	9·6	10·8	8·5	9·9
	Stornoway	31·792	10·2	9·8	6·5	5·9	5·7	6·1	5·3	9·1	10·5	11·1	8·7	11·1
	Auchinraith	31·951	10·8	8·6	7·2	5·4	6·1	6·3	8·2	9·3	9·1	11·0	7·6	10·4
	Hoy Sound West	32·693	9·2	9·0	7·8	5·6	4·8	4·4	5·0	9·8	10·1	12·8	11·3	10·2
	Rhinns of Islay	33·434	9·2	8·0	7·7	5·3	6·0	5·5	6·0	10·6	9·2	11·4	11·2	9·9
	Hillend House	33·445	9·9	8·0	6·7	5·3	6·4	6·9	7·6	10·6	9·8	11·5	8·1	9·2
	Mean of 7 Stations	32·310	10·0	8·7	7·3	5·4	5·8	6·0	6·2	10·2	9·8	11·2	9·3	10·1
35–40...	Bressay	36·488	11·6	8·7	7·2	5·6	5·3	3·5	4·9	9·0	8·9	12·7	9·8	12·8
	Hoy Sound East	37·007	9·6	10·3	8·1	5·8	4·6	4·1	4·5	8·7	9·4	12·3	11·5	11·1
	Dumfries	37·045	12·2	7·9	7·2	5·1	6·5	6·1	6·5	9·6	9·3	11·1	8·3	10·2
	Sandwick	38·853	9·4	8·8	8·3	5·9	5·0	4·6	4·9	9·0	9·8	12·2	11·5	10·6
	Cape Wrath	39·371	9·4	9·5	6·4	5·6	5·3	5·4	5·5	11·3	11·0	10·6	10·4	9·5
	Rona	39·470	9·4	8·9	5·8	4·5	5·9	6·7	5·8	10·0	10·7	10·7	9·9	11·7
	Mean of 6 Stations	38·042	10·3	9·0	7·2	5·4	5·4	5·1	5·3	9·6	9·9	11·6	10·2	11·0
40–45...	Pladda	40·141	11·0	8·3	8·9	6·1	5·6	6·5	6·0	9·1	9·4	11·0	8·4	9·7
	Ushenish	43·905	9·4	10·2	6·9	5·9	4·7	5·2	4·7	8·7	10·6	10·9	10·8	12·0
	Mull of Kintyre	44·166	10·5	7·5	8·4	6·9	5·8	7·9	6·2	11·8	8·2	9·5	8·8	8·5
	Auchendrane House	44·285	11·3	9·2	7·4	5·5	5·7	6·4	5·6	8·9	9·2	10·5	9·4	10·9
	Glasgow Observatory	44·411	12·0	8·1	8·2	5·3	6·2	6·4	6·9	10·2	8·6	9·8	8·0	10·3
	Mean of 5 Stations	43·382	10·8	8·7	8·0	5·9	5·6	6·5	5·9	9·7	9·2	10·3	9·1	10·3

45–50...	Ardnamurchan	45·594	10·6	8·4	7·5	5·7	5·4	5·2	5·9	9·8	10·0	11·5	9·7	10·3
	Lismore	46·215	10·6	9·1	7·0	6·0	6·5	5·9	5·9	10·1	9·3	10·7	7·5	11·4
	Baillieston	46·471	11·1	8·5	6·6	5·7	6·4	6·4	7·8	9·7	9·2	10·3	8·0	10·3
	Devaar	47·312	13·0	8·5	8·4	5·5	5·9	5·3	5·5	9·4	8·5	10·5	9·8	9·7
	Ryat Linn	47·801	12·3	10·4	7·3	5·6	5·2	5·5	6·0	8·4	9·6	10·4	8·0	11·3
	Largs	48·920	12·0	8·1	7·6	6·0	5·3	5·6	6·4	10·5	9·2	9·3	9·1	10·9
	South Cairn	49·603	11·9	6·9	8·4	6·8	6·6	6·3	7·2	8·4	8·3	10·2	9·5	9·5
	Waulk-Glen Reservoir	49·845	12·7	10·7	7·5	5·4	4·9	5·3	5·8	8·3	9·5	10·1	8·1	11·7
	Mean of 8 Stations	47·720	11·8	8·8	7·6	5·8	5·8	5·7	6·3	9·3	9·2	10·4	8·7	10·6
50–55...	Netherplace	50·143	12·3	9·8	7·7	5·5	4·8	5·2	5·9	8·0	9·3	10·5	9·0	12·0
	Callton Mor	54·253	10·5	7·8	6·9	5·5	5·8	5·5	5·4	·9	10·5	11·1	9·4	11·7
	Castle Toward	54·554	12·7	8·4	7·5	5·5	5·7	5·5	5·8	10·7	9·3	9·8	8·3	10·8
	Mean of 3 Stations	52·983	11·8	8·7	7·4	5·5	5·4	5·4	5·7	9·5	9·7	10·5	8·9	11·5
55–60...	Middleton	56·682	12·7	9·7	7·4	5·4	5·1	5·6	6·2	8·6	9·8	10·2	8·3	11·0
60–65...	Aird's House	63·640	11·0	10·9	6·9	6·6	5·6	5·4	5·9	9·4	9·0	9·9	7·3	12·1
65–70...	Greenock	66·156	13·8	10·8	8·0	5·3	4·8	5·2	4·7	8·6	8·6	9·8	8·4	12·0
	Inverary Castle	67·370	11·9	9·5	5·8	6·8	4·7	4·7	5·5	8·9	9·0	10·9	8·8	13·5
	Bernera	68·027	9·1	7·0	7·4	4·9	5·1	5·8	7·2	9·6	10·7	9·6	9·4	14·2
	Mean of 3 Stations	67·184	11·6	9·1	7·1	5·7	4·	5·2	5·8	9·0	9·4	10·1	8·9	13·2

TABLE I. (*continued*).

SCOTLAND.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
			Monthly percentage of Annual Fall.											
in. in.	*Western District* (continued).	in.												
70–75...	Sound of Mull	72·159	11·8	10·5	6·8	5·2	4·4	4·4	4·9	7·8	10·3	10·8	10·0	13·1
	Oronsay	72·359	10·0	10·4	5·3	5·2	6·2	6 2	5·8	10·8	10·1	10·4	8·2	11·4
	Mean of 2 Stations	72·259	10·9	10·5	6·0	5·2	5·3	5·3	5·4	9·3	10·2	10·6	9·1	12·2
75–80...	Raasay	77·120	11·5	10·3	7·2	4·6	4·8	5·0	5·8	7·1	10·3	10·6	8·7	14·1
	Arddarrock	78·321	12·1	9·9	8·7	5·9	4·7	5·4	4·9	8·5	9·2	10·3	9·0	11·4
	Tyree Hynish	79·992	13·2	9·9	9·8	5·7	4·8	4·8	4·4	7·7	9·1	9·3	9·4	11·9
	Mean of 3 Stations	78·478	12·3	10·0	8 6	5·4	4·8	5·1	5·0	7·8	9·5	10·1	9·0	12·4
80–85...	Kyleakin	82·067	11·9	12·8	7·4	5·4	4·5	6·0	3·7	6·5	9·2	9·8	9·0	13·8
100–105	Portree	104·261	12·7	10·7	7·6	5·2	4·5	4·7	5·2	7·1	9·3	10·0	9·0	14·0
	Eastern District.													
20–25...	Isle of May	20·482	9·6	6·1	4·9	6·4	8·2	7·6	8·1	11·6	10·5	10·8	7·4	8·8
	Girdleness	22·718	10·1	5·4	7·1	5·8	7·0	6·4	6·2	11·6	10·4	10·8	9·0	10·2
	Smeaton	23·263	10·3	5·6	7·0	5·9	7·4	7·9	10·2	9·9	9·2	12·1	7·1	7·4
	Perth Academy	23·584	13·3	7·7	6·8	5·6	5·9	7·2	6·9	12·0	8·9	9·2	6·8	9·7
	Kinnairdhead	24·168	7·7	7·8	6·5	5·7	5·6	5·0	7·0	11·4	11·1	11·0	11·2	10·0
	Springwood Park	24·663	9·6	5·6	7·4	5·9	7·7	7·4	9·1	9·3	8·8	11·4	8·5	9·3
	Nosshead	24·699	6·8	7·8	8·5	5·0	5·6	4·7	5·7	10·9	9·8	12·4	11·9	10·9
	Mean of 7 Stations	23·368	9·6	6·6	6·9	5·8	6·8	6·6	7·6	10·9	9·8	11·1	8·8	9·5

25–30...	Dunnethead	25·401	6·6	8·6	7·2	5·8	5·4	6·0	7·2	10·4	9·7	12·2	11·4	9·5
	Buchanness	25·588	9·7	7·1	7·9	6·2	6·6	5·9	6·0	9·9	10·0	10·4	9·2	11·1
	Millfield	25·630	12·7	6·0	7·0	6·0	7·4	6·3	8·8	9·7	9·3	11·0	8·3	7·5
	Cromarty	25·941	9·0	7·9	6·4	5·2	5·9	6·5	7·8	11·3	11·2	10·3	9·8	8·7
	Culloden	27·084	10·7	8·2	6·3	6·1	5·7	6·3	8·3	11·8	10·3	9·5	8·6	8·2
	Dunrobin	27·692	9·7	10·7	7·8	5·1	4·7	5·5	5·4	9·2	10·3	11·5	9·6	10·5
	Mungo's Walls	28·494	10·0	5·9	7·6	6·1	7·8	7·2	8·6	8·9	8·1	11·2	9·0	9·6
	Balfour	28·589	12·3	7·7	6·0	5·2	6·7	5·8	7·8	8·7	10·0	11·5	8·3	10·0
	Pentland Skerries	28·763	8·7	7·9	9·0	4·9	5·5	5·3	5·5	10·0	8·0	11·7	12·3	11·2
	Nookton	28·988	10·8	7·1	6·4	5·6	7·4	6·8	8·5	9·7	9·7	10·6	8·0	9·4
	Inveresk	29·016	9·6	7·3	6·7	6·1	7·4	7·6	8·3	11·0	9·5	10·7	7·6	8·2
	Arbroath	29·050	10·6	6·2	6·7	5·2	7·1	7·1	8·0	10·5	10·2	10·8	7·5	10·1
	Gordon Castle	29·192	8·0	6·5	6·6	6·2	6·3	6·7	9·1	12·4	10·6	10·3	9·6	7·7
	Aberdeen, Rose Street	29·433	10·7	6·9	8·0	5·7	6·5	6·2	6·5	11·6	8·6	9·9	8·4	11·0
	Barry Village	29·729	11·1	6·6	7·2	5·0	6·9	6·6	8·2	9·9	10·0	11·3	7·8	9·4
	Thirlestane	29·977	11·5	8·0	9·3	5·6	5·8	6·2	6·5	8·3	8·6	11·2	9·7	9·3
	Mean of 16 Stations	28·035	10·1	7·4	7·3	5·6	6·4	6·4	7·5	10·2	9·6	10·9	9·1	9·5
30–35...	North Ronaldsay	31·015	10·4	8·6	7·3	5·4	5·4	4·2	5·4	9·0	8·5	13·2	10·7	11·9
	Start Point	31·371	9·3	7·9	7·8	6·0	5·2	3·8	4·9	10·2	9·6	13·0	9·9	12·4
	Balfour Castle	32·408	8·7	8·3	7·4	6·3	4·7	4·3	4·6	10·7	10·4	12·9	11·2	10·5
	Kerse	32·960	12·4	9·5	7·9	5·2	5·7	6·4	7·5	9·5	8·7	9·8	7·5	9·9
	Bowhill Gardens	33·033	11·3	8·0	8·3	4·9	6·9	7·9	7·2	8·8	8·9	11·0	6·3	10·5
	Kettins	33·172	11·2	6·3	6·7	4·8	6·3	7·9	9·2	10·5	9·6	10·0	7·4	10·1
	Braemar	33·404	10·4	7·0	7·2	5·9	5·0	8·2	6·7	10·6	9·2	10·8	7·7	11·3
	Castle Newe	33·500	9·1	6·6	8·2	6·5	6·2	6·6	6·7	10·3	9·5	11·2	9·1	10·0
	Auchterarder House	34·315	12·1	7·7	6·6	6·1	4·8	7·1	7·2	10·7	9·4	10·0	7·0	11·3
	Craigton	34·876	12·1	7·0	7·4	4·8	5·8	6·5	8·1	9·4	10·0	11·4	7·8	9·7
	The Burn, Kincardine	34·910	11·6	7·5	7·2	5·2	5·9	7·2	6·8	9·4	9·2	11·1	7·5	11·4
	Mean of 11 Stations	33·179	10·8	7·7	7·4	5·6	5·6	6·4	6·7	9·9	9·4	11·3	8·4	10·8

TABLE I. (*continued*).

SCOTLAND.

Limiting Amounts.	Name of Station.	Mean Annual Fall in the period.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		Monthly percentage of Annual Fall.												
in. in.	*Eastern District* (continued).	in.												
35–40...	Hillhead, Monikie	35·187	12·0	6·8	7·0	4·8	5·9	6·7	8·1	9·4	10·1	11·7	7·8	9·7
	Trinity Gask	35·324	14·4	7·3	6·8	4·9	5·2	6·9	7·2	10·8	8·8	9·7	7·2	10·8
	Loch Leven	35·780	11·2	7·5	7·1	5·3	6·1	6·8	6·8	10·0	9·2	11·6	7·9	10·4
	Kippenross	36·165	13·9	7·8	7·5	4·8	4·4	5·4	6·9	10·3	7·6	11·4	8·2	11·8
	Cobbinshaw Loch	37·450	11·4	8·1	7·1	5·8	5·9	6·5	7·6	9·4	9·1	11·6	8·5	9·0
	North Esk Reservoir	38·014	11·5	9·2	6·7	5·9	6·2	6·2	7·7	9·3	8·7	11·3	8·3	9·0
	Mean of 6 Stations	36·320	12·4	7·8	7·0	5·3	5·6	6·4	7·4	9·9	8·9	11·2	8·0	10·1
40–45...	Perth, Early Bank	40·471	14·1	8·5	6·8	4·4	5·7	6·8	9·6	10·1	8·2	9·2	7·5	9·1
	Polmaise Gardens	41·300	12·8	10·4	7·3	5·5	4·7	6·2	7·2	9·8	8·1	9·9	7·3	10·8
	Deanston	43·991	12·3	9·0	7·2	5·3	5·6	6·0	7·0	10·4	8·9	10·2	7·5	10·6
	Mean of 3 Stations	41·921	13·1	9·3	7·1	5·1	5·3	6·3	7·9	10·1	8·4	9·8	7·4	10·2
45–50...	Lanrick Castle	48·805	12·7	9·7	7·6	5·0	4·7	6·3	6·4	9·9	8·6	10·2	7·9	11·0
60–65...	Aberfoyle	61·820	13·5	9·4	6·9	5·7	4·4	6·2	5·7	9·1	9·2	9·7	8·0	12·2
	Bridge of Turk	61·890	12·7	8·9	6·8	5·8	3·9	6·3	5·6	9·6	9·3	10·1	8·4	12·6
	Mean of 2 Stations	61·855	13·1	9·2	6·8	5·8	4·1	6·3	5·6	9·4	9·2	9·9	8·2	12·4

Ireland.

	Western District.													
30–35...	Cork Institution	34·771	13·2	5·7	9·3	5·1	7·3	5·7	5·3	8·6	8·4	9·4	9·5	12·5
35–40...	......	......	......	......	......	......	......	......	......	......	......	......	......	......
40–45...	Waterford	40·669	12·8	5·6	7·8	5·9	6·8	5·9	7·0	9·5	9·4	9·2	8·6	11·5
	Florence Court	44·368	12·5	6·9	9·5	5·2	5·6	6·4	6·6	8·8	7·7	9·5	10·1	11·2
	Mean of 2 Stations	42·519	12·7	6·2	8·7	5·5	6·2	6·2	6·8	9·1	8·6	9·3	9·4	11·3
45–50...	Killaloe	47·654	10·2	8·1	8·8	6·0	6·9	6·7	6·1	9·6	9·7	10·0	9·1	8·8
	Eastern District.													
25–30...	Dublin, Black Rock	27·096	10·7	5·6	9·5	5·9	8·5	7·2	6·1	9·1	8·7	10·5	8·2	10·0
	Tullamore	27·938	10·0	6·1	8·5	5·5	7·8	8·0	7·0	10·8	8·8	10·2	8·7	8·6
	Mean of 2 Stations	27·517	10·4	5·8	9·0	5·7	8·2	7·6	6·5	9·9	8·8	10·4	8·4	9·3
30–35...	Belfast, Queen's College	34·225	11·0	7·2	9·1	6·2	7·3	6·5	6·7	9·9	7·8	10·2	9·4	8·7
35–40...	Belfast, Linen Hall	36·767	10·9	7·2	9·1	6·1	7·5	6·7	7·0	9·5	7·6	10·2	9·2	9·0
	Portarlington	36·857	10·0	6·2	8·3	5·6	7·8	7·4	7·5	10·2	8·8	11·1	8·3	8·8
	Mean of 2 Stations	36·812	10·5	6·7	8·7	5·8	7·7	7·0	7·3	9·8	8·2	10·7	8·7	8·9
40–45...	Fassaroe	41·822	13·0	7·6	9·7	5·0	6·9	7·1	5·6	7·8	7·4	10·8	8·3	10·8

TABLE II.—Mean Percentage

ENGLAND AND WALES.

Mean Annual Fall. Between	No. of Stations.	Jan.	Feb.	March.	April	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		WESTERN DISTRICT, 1850–59.											
in. in.													
15– 20	......	......	......	......	......	......	......	......	......	......	......	......	......
20– 25	8	7·9	5·5–	5·7	7·2	7·0	10·2	10·6	10·5	9·1	11·1+	8·5	6·7
25– 30	11	9·1	5·4–	5·5	6·9	7·2	9·0	9·9	9·8	8·4	11·7+	8·5	8·6
30– 35	9	9·3	6·1	5·7–	7·2	6·3	8·4	8·7	9·4	8·7	11·7+	9·3	9·2
35– 40	5	10·4	6·9	6·6	7·0	5·8–	8·5	8·1	9·0	7·9	11·3+	9·0	9·5
40– 45	4	11·4+	7·4	6·5	6·9	5·8–	7·7	7·7	8·6	7·6	10·9	9·2	10·3
45– 50	2	9·3	7·7	5·3	5·6	4·8–	9·4	9·4	10·9+	8·7	10·9+	8·8	9·2
50– 55	2	10·7+	7·1	6·4	7·3	5·8–	7·7	7·7	9·2	8·0	10·6	9·3	10·2
55– 60	1	13·9+	7·8	5·7	4·9	4·8–	7·0	7·7	8·1	8·4	10·7	8·5	12·5
60– 65	1	13·9+	9·1	5·8	5·5	4·3–	6·4	7·4	9·1	7·0	10·2	8·7	12·6
65– 70	......	......	......	......	......	......	......	......	......	......	......	......	......
70– 75	2	14·1+	9·6	6·0	5·5	4·0–	6·4	6·8	9·0	7·2	9·8	8·9	12·7
125–130	1	13·6+	9·6	6·4	6·0	4·5–	6·8	7·2	8·5	7·2	10·2	8·1	11·9
150–155	......	......	......	......	......	......	......	......	......	......	......	......	......
Mean...	......	11·2	7·5	6·0	6·4	5·5	7·9	8·3	9·3	8·0	10·8	8·8	10·3
		Note.—In the upper portion of this Table the affixed + and – indi-											
		Departure of mean percentage for each											
15– 20	......	......	......	......	......	......	......	......	......	......	......	......	......
20– 25	......	–3·3	–2·0	– ·3	+ ·8	+1·5	+2·3	+2·3	+1·2	+1·1	+ ·3	– ·3	–3·6
25– 30	......	–2·1	–2·1	– ·5	+ ·5	+1·7	+1·1	+1·6	+ ·5	+ ·4	+ ·9	– ·3	–1·7
30– 35	......	–1·9	–1·4	– ·3	+ ·8	+ ·8	+ ·5	+ ·4	+ ·1	+ ·7	+ ·9	+ ·5	–1·1
35– 40	......	– ·8	– ·6	+ ·6	+ ·6	+ ·3	+ ·6	– ·2	– ·3	– ·1	+ ·5	+ ·2	– ·8
40– 45	......	+ ·2	– ·1	+ ·5	+ ·5	+ ·3	– ·2	– ·6	– ·7	– ·4	+ ·1	+ ·4	0·0
45– 50	......	–1·9	+ ·2	– ·7	– ·8	– ·7	+1·5	+1·1	+1·6	+ ·7	+ ·1	0·0	–1·1
50– 55	......	– ·5	– ·4	+ ·4	+ ·9	+ ·3	– ·2	– ·6	– ·1	0·0	– ·2	+ ·5	– ·1
55– 60	......	+2·7	+ ·3	– ·3	–1·5	– ·7	– ·9	– ·6	–1·2	+ ·4	– ·1	– ·3	+2·2
60– 65	......	+2·7	+1·6	– ·2	– ·9	–1·2	–1·5	– ·9	– ·2	–1·0	– ·6	– ·1	+2·3
65– 70	......	......	......	......	......	......	......	......	......	......	......	......	......
70– 75	......	+2·9	+2·1	0·0	– ·9	–1·5	–1·5	–1·5	– ·3	– ·8	–1·0	+ ·1	+2·4
125–130	......	+2·4	+2·1	+ ·4	– ·4	–1·0	–1·1	–1·1	– ·8	– ·8	– ·6	– ·7	+1·6
150–155	......	......	......	......	......	......	......	......	......	......	......	......	......
		CENTRAL DISTRICT, 1850–59.											
15–20	1	7·7	4·5–	4·8	7·0	6·2	11·1	11·8	13·2+	8·6	11·1	8·3	5·7
20–25	9	8·5	4·4–	5·0	7·0	7·8	9·4	11·7	10·6	9·0	11·9+	8·3	6·4
25–30	7	8·8	4·5–	5·3	7·6	8·0	8·6	9·6	9·5	9·0	13·3+	8·5	7·3
30–35	......	......	......	......	......	......	......	......	......	......	......	......	......
35–40	......	......	......	......	......	......	......	......	......	......	......	......	......
40–45	......	......	......	......	......	......	......	......	......	......	......	......	......
45–50	......	......	......	......	......	......	......	......	......	......	......	......	......
50–55	......	......	......	......	......	......	......	......	......	......	......	......	......
Mean...	......	8·3	4·5	5·0	7·2	7·3	9·7	11·0	11·1	8·9	12·1	8·4	6·5
15–20	......	– ·6	0·0	– ·2	– ·2	–1·1	+1·4	+ ·8	+2·1	– ·3	–1·0	– ·1	– ·8
20–25	......	+ ·2	– ·1	0·0	– ·2	+ ·5	– ·3	+ ·7	– ·5	+ ·1	– ·2	– ·1	– ·1
25–30	......	+ ·5	0·0	+ ·3	+ ·4	+ ·7	–1·1	–1·4	–1·6	+ ·1	+1·2	+ ·1	+ ·8
30–35	......	......	......	......	......	......	......	......	......	......	......	......	......
35–40	......	......	......	......	......	......	......	......	......	......	......	......	......
40–45	......	......	......	......	......	......	......	......	......	......	......	......	......
45–50	......	......	......	......	......	......	......	......	......	......	......	......	......
50–55	......	......	......	......	......	......	......	......	......	......	......	......	......

in each Group.

ENGLAND AND WALES.

No. of Stations.	Western District, 1860–69.											
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8·6	6·5	7·7	4·8−	8·4	11·3	4·8	10·9	12·8+	9·8	5·9	8·5
6	7·8	6·0	7·3	5·8−	8·1	8·1	8·3	10·4+	10·4	10·1	8·1	9·6
11	10·0	6·6	7·9	5·7−	8·3	8·4	6·5	8·7	10·5+	10·2	7·7	9·5
30	9·4	6·8	7·9	5·3−	7·2	7·7	7·0	9·3	10·3	10·7+	8·7	9·7
18	9·3	7·0	7·8	5·4−	7·0	7·4	7·0	9·2	10·2	10·7+	9·0	10·0
19	10·8+	7·5	7·6	5·1−	6·6	6·8	6·4	8·5	9·9	10·7	9·4	10·7
12	10·4	7·5	7·7	5·2−	6·2	6·6	6·3	8·9	10·3	10·8+	9·5	10·6
8	10·2	8·0	7·8	5·3−	6·2	6·7	6·3	8·7	10·2	10·4	9·6	10·6+
4	10·0	8·5	7·6	5·3−	5·8	6·2	5·8	8·7	10·1	10·9	10·0	11·1+
1	11·2+	8·8	7·7	6·0	5·2−	5·6	5·4	8·9	10·3	10·0	10·8	10·1
......	......	......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......	......	......
1	11·1	9·6	8·6	5·4	5·0−	5·4	5·3	8·3	9·3	9·7	10·3	12·0+
Mean.	9·9	7·5	7·8	5·4	6·7	7·3	6·3	9·1	10·4	10·4	9·0	10·2

cate the months of maximum and minimum percentage respectively.

group from the mean of the district.

......	−1·3	−1·0	− ·1	− ·6	+1·7	+4·0	−1·5	+1·8	+2·4	− ·6	−3·1	−1·7
......	−2·1	−1·5	− ·5	+ ·4	+1·4	+ ·8	+2·0	+1·3	0·0	− ·3	− ·9	− ·6
......	+ ·1	− ·9	+ ·1	+ ·3	+1·6	+1·1	+ ·2	− ·4	+ ·1	− ·2	−1·3	− ·7
......	− ·5	− ·7	+ ·1	− ·1	+ ·5	+ ·4	+ ·7	+ ·2	− ·1	+ ·3	− ·3	− ·5
......	− ·6	− ·5	0·0	0·0	+ ·3	+ ·1	+ ·7	+ ·1	− ·2	+ ·3	0·0	− ·2
......	+ ·9	0·0	− ·2	− ·3	− ·1	− ·5	+ ·1	− ·6	− ·5	+ ·3	+ ·4	+ ·5
......	+ ·5	0·0	− ·1	− ·2	− ·5	− ·7	0·0	− ·2	− ·1	+ ·4	+ ·5	+ ·4
......	+ ·3	+ ·5	0·0	− ·1	− ·5	− ·6	0·0	− ·4	− ·2	0·0	+ ·6	+ ·4
......	+ ·1	+1·0	− ·2	− ·1	− ·9	−1·1	− ·5	− ·4	− ·3	+ ·5	+1·0	+ ·9
......	+1·3	+1·3	− ·1	+ ·6	−1·5	−1·7	− ·9	− ·2	− ·1	− ·4	+1·8	− ·1
......	......	......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......	......	......
......	+1·2	+2·1	+ ·8	0·0	−1·7	−1·9	−1·0	− ·8	−1·1	− ·7	+1·3	+1·8

	Central District, 1860–69.											
1	9·4	6·0	7·3	5·4−	8·3	9·5	7·5	10·8+	10·4	9·8	7·8	7·8
11	8·2	6·3	8·0	5·7−	9·1	8·8	8·0	10·3+	10·1	9·8	7·4	8·3
14	9·7	6·4	8·0	5·6−	8·3	9·3	7·2	9·1	10·4+	9·7	7·6	8·7
5	10·4	6·6	7·9	5·1−	7·6	8·4	6·5	8·8	10·9+	10·3	7·9	9·6
......	......	......	......	......	......	......	......	......	......	......	......	......
1	8·4	6·9	8·1	5·8−	6·1	7·9	6·9	9·5	10·0	10·8+	9·2	10·4
1	8·6	6·2	6·4	6·0−	6·7	8·7	7·2	9·7	9·5	11·3+	10·1	9·6
1	8·8	8·3	8·0	6·0−	6·8	7·6	6·8	8·7	9·8	10·3+	9·8	9·1
Mean.	9·1	6·7	7·7	5·6	7·6	8·6	7·1	9·6	10·1	10·3	8·5	9·1

......	+ ·3	− ·7	− ·4	− ·2	+ ·7	+ ·9	+ ·4	+1·2	+ ·3	− ·5	− ·7	−1·3
......	− ·9	− ·4	+ ·3	+ ·1	+1·5	+ ·2	+ ·9	+ ·7	0·0	− ·5	−1·1	− ·8
......	+ ·6	− ·3	+ ·3	0·0	+ ·7	+ ·7	+ ·1	− ·5	+ ·3	− ·6	− ·9	− ·4
......	+1·3	− ·1	+ ·2	− ·5	0·0	− ·2	− ·6	− ·8	+ ·8	0·0	− ·6	+ ·5
......	......	......	......	......	......	......	......	......	......	......	......	......
......	− ·7	+ ·2	+ ·4	+ ·2	−1·5	− ·7	− ·2	− ·1	− ·1	+ ·5	+ ·7	+1·3
......	− ·5	− ·5	−1·3	+ ·4	− ·9	+ ·1	+ ·1	+ ·1	− ·6	+1·0	+1·6	+ ·5
......	− ·3	+1·6	+ ·3	+ ·4	− ·8	−1·0	− ·2	− ·9	− ·3	0·0	+1·3	0·0

TABLE II.

ENGLAND AND WALES.

Mean Annual Fall. Between	No. of Stations.	Eastern District, 1850-59. Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
in. in.													
15-20	4	7·7	4·7−	5·3	6·9	7·4	8·7	12·3+	11·8	9·3	10·7	8·9	6·3
20-25	12	7·9	4·8−	5·1	7·1	8·5	8·2	12·1	10·4	9·0	12·3+	8·6	6·0
25-30	12	8·7	4·8−	5·3	7·0	7·5	7·3	11·0	9·6	9·5	12·7+	9·5	7·1
30-35	2	9·7	4·2−	5·5	6·9	7·6	7·6	8·7	8·1	10·0	14·9+	8·9	7·9
35-40	1	9·7	4·5−	6·8	6·7	7·0	7·8	9·4	7·8	10·1	14·3+	8·2	7·7
50-55	...	...	...	...	...	...	...	..	...	...	...	...	...
Mean...	...	8·5	4·6	5·6	6·9	7·6	7·9	10·7	9·5	9·6	13·0	8·8	7·0

Departure of mean percentage for each

15-20	...	− ·8	+ ·1	− ·3	0·0	− ·2	+ ·8	+1·6	+2·3	− ·3	−2·3	+ ·1	− ·7
20-25	...	− ·6	+ ·2	− ·5	+ ·2	+ ·9	+ ·3	+1·4	+ ·9	− ·6	− ·7	− ·2	−1·0
25-30	...	+ ·2	+ ·2	− ·3	+ ·1	− ·1	− ·6	+ ·3	+ ·1	− ·1	− ·3	+ ·7	+ ·1
30-35	...	+1·2	− ·4	− ·1	0·0	0·0	− ·3	−2·0	−1·4	+ ·4	+1·9	+ ·1	+ ·9
35-40	...	+1·2	− ·1	+1·2	− ·2	− ·6	− ·1	−1·3	−1·7	+ ·5	+1·3	− ·6	+ ·7
50-55	...	...	...	...	...	...	...	...	...	...	...	...	...

SCOTLAND.

Mean Annual Fall. Between	No. of Stations.	Western District, 1850-59. Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
in. in.													
20- 25	1	10·9	8·2	6·2	7·4	4·8−	9·0	9·4	7·3	5·1	10·8	9·4	11·5+
25- 30	1	11·4+	7·8	5·7	5·3−	6·3	9·4	10·1	9·4	8·1	10·1	6·4	10·0
30- 35	3	11·0	8·3	6·7	5·9	4·6−	6·7	8·9	8·5	8·1	10·3	9·4	11·6+
35- 40	4	11·1	7·6	6·6	5·5	4·9−	8·0	9·2	8·4	7·5	10·9	8·9	11·4+
40- 45	2	11·0+	8·2	6·3	7·8	5·5−	8·5	8·2	9·5	6·5	9·5	8·6	10·4
45- 50	2	10·5	8·6	6·9	6·8	5·7−	8·5	8·5	9·2	6·6	9·9	7·7	11·1+
50- 55	1	11·7	7·9	6·4	5·7	5·4−	6·5	9·2	8·7	7·3	10·4	8·2	12·6+
55- 60	...	...	...	...	...	...	...	...	...	...	...	...	...
60- 65	...	...	...	...	...	...	...	...	...	...	...	...	...
65- 70	1	13·0	9·2	6·9	6·4	5·0−	6·6	7·4	7·8	6·7	10·1	7·7	13·2+
70- 75	1	14·4	9·3	6·6	4·9	4·0−	5·4	6·9	6·1	8·0	10·1	9·5	14·8+
75- 80	...	...	...	...	...	...	...	...	...	...	...	...	...
80- 85	...	...	...	...	...	...	...	...	...	...	...	...	...
100-105	...	...	...	...	...	...	...	...	...	...	...	—	...
Mean ...	...	11·7	8·4	6·5	6·2	5·1	7·6	8·7	8·3	7·1	10·2	8·4	11·8

(continued).

ENGLAND AND WALES.

No. of Stations.	Eastern District, 1860–69.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5·5	5·2	7·6	4·9−	8·4	7·3	8·9	11·8+	10·3	10·4	10·6	9·1
34	8·3	6·3	7·9	5·4−	8·7	8·8	8·2	10·1+	9·6	9·4	8·6	8·7
26	9·6	6·3	8·1	5·6−	8·0	8·0	7·4	9·1	9·7	10·3+	8·8	9·0
7	10·4	6·9	7·6	4·6−	7·3	7·6	7·0	8·7	10·4	11·1+	8·8	9·6
2	11·3	6·7	7·8	4·4−	7·0	7·4	6·1	8·3	10·7	11·5+	8·8	10·0
1	11·6+	9·5	8·7	6·2	5·8	7·5	5·5−	5·6	8·5	10·8	9·9	10·4
Mean...	9·5	6·8	7·9	5·2	7·5	7·8	7·2	8·9	9·9	10·6	9·2	9·5

group from the mean of the district.

...	−4·0	−1·6	− ·3	− ·3	+ ·9	− ·5	+1·7	+2·9	+ ·4	− ·2	+1·4	− ·4
...	−1·2	− ·5	0·0	+ ·2	+1·2	+1·0	+1·0	+1·2	− ·3	−1·2	− ·6	− ·8
...	+ ·1	− ·5	+ ·2	+ ·4	+ ·5	+ ·2	+ ·2	+ ·2	− ·2	− ·3	− ·4	− ·5
...	+ ·9	+ ·1	− ·3	− ·6	− ·2	− ·2	− ·2	− ·2	+ ·5	+ ·5	− ·4	+ ·1
...	+1·8	− ·1	− ·1	− ·8	− ·5	− ·4	−1·1	− ·6	+ ·8	+ ·9	− ·4	+ ·5
...	+2·1	+2·7	+ ·8	+1·0	−1·7	− ·3	−1·7	−3·3	−1·4	+ ·2	+ ·7	+ ·9

SCOTLAND.

No. of Stations.	Western District, 1860–69.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
...	...	...	...	...	...	...	...	...	...	...	...	...
4	11·8+	7·7	7·3	5·8	6·8	5·6−	6·3	8·9	9·0	11·0	9·3	10·5
7	10·0	8·7	7·3	5·4−	5·8	6·0	6·2	10·2	9·8	11·2+	9·3	10·1
6	10·3	9·0	7·2	5·4	5·4	5·1−	5·3	9·6	9·9	11·6+	10·2	11·0
5	10·8+	8·7	8·0	5·9	5·6−	6·5	5·9	9·7	9·2	10·3	9·1	10·3
8	11·8+	8·8	7·6	5·8	5·8	5·7−	6·3	9·3	9·2	10·4	8·7	10·6
3	11·8+	8·7	7·4	5·5	5·4−	5·4	5·7	9·5	9·7	10·5	8·9	11·5
1	12·7+	9·7	7·4	5·4	5·1−	5·6	6·2	8·6	9·8	10·2	8·3	11·0
1	11·0	10·9	6·9	6·6	5·6	5·4−	5·9	9·4	9·0	9·9	7·3	12·1+
3	11·6	9·1	7·1	5·7	4·9−	5·2	5·8	9·0	9·4	10·1	8·9	13·2+
2	10·9	10·5	6·0	5·2−	5·3	5·3	5·4	9·3	10·2	10·6	9·1	12·2+
3	12·3	10·0	8·6	5·4	4·8−	5·1	5·0	7·8	9·5	10·1	9·0	12·4+
1	11·9	12·8	7·4	5·4	4·5	6·0	3·7−	6·5	9·2	9·8	9·0	13·8+
1	12·7	10·7	7·6	5·2	4·5−	4·7	5·2	7·1	9·3	10·0	9·0	14·0+
Mean...	11·5	9·6	7·4	5·6	5·4	5·5	5·6	8·8	9·5	10·4	8·9	11·8

TABLE II.

SCOTLAND.

Departure of mean percentage for each

Mean Annual Fall. Between	No. of Stations.	Western District, 1850–59 (*continued*).											
		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
in. in.													
20– 25	...	− ·8	−·2	−·3	+1·2	− ·3	+1·4	+ ·7	−1·0	−2·0	+ ·6	+1·0	− ·3
25– 30	...	− ·3	−·6	−·8	− ·9	+1·2	+1·8	+1·4	+1·1	+1·0	+ ·1	−2·0	−1·8
30– 35	...	− ·7	−·1	+·2	− ·3	− ·5	− ·9	+ ·2	+ ·2	+1·0	+ ·1	+1·0	− ·2
35– 40	...	− ·6	−·8	+·1	− ·7	− ·2	+ ·4	+ ·5	+ ·1	+ ·4	+ ·7	+ ·5	− ·4
40– 45	...	− ·7	−·2	−·2	+1·6	+ ·4	+ ·9	− ·5	+1·2	− ·6	− ·7	+ ·2	−1·4
45– 50	...	−1·2	+·2	+·4	+ ·6	+ ·6	+ ·9	− ·2	+ ·9	− ·5	− ·3	− ·7	− ·7
50– 55	...	0·0	−·5	−·1	− ·5	+ ·3	−1·1	+ ·5	+ ·4	+ ·2	+ ·2	− ·2	+ ·8
55– 60	...	...	...	...	...	...	...	...	...	...	...	...	...
60– 65	...	...	...	...	...	...	...	...	...	...	...	...	...
65– 70	...	+1·3	+·8	+·4	+ ·2	− ·1	−1·0	−1·3	− ·5	− ·4	− ·1	− ·7	+1·4
70– 75	...	+2·7	+·9	+·1	−1·3	−1·1	−2·2	−1·8	−2·2	+ ·9	− ·1	+1·1	+3·0
75– 80	...	...	...	...	...	...	...	...	...	...	...	...	...
80– 85	...	...	...	...	...	...	...	...	...	...	...	...	...
100–105	...	...	...	...	...	...	...	...	...	...	...	...	...

Eastern District, 1850–59.

15–20	3	8·4	5·4	5·4−	7·1	5·5	8·2	9·2	10·9	8·6	11·8+	9·9	9·6
20–25	10	9·9	6·4	5·5	5·8	5·4−	8·6	9·4	9·3	8·1	12·4+	9·5	9·7
25–30	7	10·7	6·8	6·2	6·3	5·5−	8·7	9·1	9·6	7·3	10·9+	9·1	9·8
30–35	5	10·9+	6·6	7·1	6·8	6·2−	8·3	8·2	8·6	8·3	10·2	9·9	8·9
35–40	4	12·2+	7·8	6·5	5·7	5·0−	7·4	8·0	8·7	7·3	11·3	9·1	11·0
40–45	1	10·2	8·0	5·0	4·8−	6·2	8·8	11·2	10·6	7·3	10·1	6·3	11·5+
45–50	...	...	...	...	...	...	...	...	...	...	...	...	...
50–55	...	...	...	...	...	...	...	...	...	...	...	...	...
55–60	...	...	...	...	...	...	...	...	...	...	...	...	...
60–65	...	...	...	...	...	...	...	...	...	...	...	...	...
Mean...	...	10·4	6·8	6·0	6·1	5·6	8·3	9·2	9·6	7·8	11·1	9·0	10·1

Departure of mean percentage for each

15–20	..	−2·0	−1·4	− ·6	+1·0	− ·1	− ·1	0·0	+1·3	+ ·8	+ ·7	+ ·9	− ·5
20–25	...	− ·5	− ·4	− ·5	− ·3	− ·2	+ ·3	+ ·2	− ·3	+ ·3	+1·3	+ ·5	− ·4
25–30	...	+ ·3	0·0	+ ·2	+ ·2	− ·1	+ ·4	− ·1	0·0	− ·5	− ·2	+ ·1	− ·3
30–35	...	+ ·5	− ·2	+1·1	+ ·7	+ ·6	0·0	−1·0	−1·0	+ ·5	− ·9	+ ·9	−1·2
35–40	...	+1·8	+1·0	+ ·5	− ·4	− ·6	− ·9	−1·2	− ·9	− ·5	+ ·2	+ ·1	+ ·9
40–45	...	− ·2	+1·2	−1·0	−1·3	+ ·6	+ ·5	+2·0	+1·0	− ·5	−1·0	−2·7	+1·4
45–50	...	...	...	...	...	...	...	...	...	...	...	...	...
50–55	...	...	...	...	...	...	...	...	...	...	...	...	...
55–60	...	...	...	...	...	...	...	...	...	...	...	...	...
60–65	...	...	...	...	...	...	...	...	...	...	...	...	...

(*continued*).

SCOTLAND.

group from the mean of the district.

No. of Stations.	Western District, 1860–69 (*continued*). Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
...	...	...	...	...	...	...	...	...	...	...	...	...
...	+ ·3	−1·9	− ·1	+ ·2	+1·4	+ ·1	+ ·7	+ ·1	− ·5	+ ·6	+ ·4	−1·3
...	−1·5	− ·9	− ·1	− ·2	+ ·4	+ ·5	+ ·6	+1·4	+ ·3	+ ·8	+ ·4	−1·7
...	−1·2	− ·6	− ·2	− ·2	0·0	− ·4	− ·3	+ ·8	+ ·4	+1·2	+1·3	− ·8
...	− ·7	− ·9	+ ·6	+ ·3	+ ·2	+1·0	+ ·3	+ ·9	− ·3	− ·1	+ ·2	−1·5
...	+ ·3	− ·8	+ ·2	+ ·2	+ ·4	+ ·2	+ ·7	+ ·5	− ·3	0·0	− ·2	−1·2
...	+ ·3	− ·9	0·0	− ·1	0·0	− ·1	+ ·1	+ ·7	+ ·2	+ ·1	0·0	− ·3
...	+1·2	+ ·1	0·0	− ·2	− ·3	+ ·1	+ ·6	− ·2	+ ·3	− ·2	− ·6	− ·8
...	− ·5	+1·3	− ·5	+1·0	+ ·2	− ·1	+ ·3	+ ·6	− ·5	− ·5	−1·6	+ ·3
...	+ ·1	− ·5	− ·3	+ ·1	− ·5	− ·3	+ ·2	+ ·2	− ·1	− ·3	0·0	+1·4
...	− ·6	+ ·9	−1·4	− ·4	− ·1	− ·2	− ·2	+ ·5	+ ·7	+ ·2	+ ·2	+ ·4
...	+ ·8	+ ·4	+1·2	− ·2	− ·6	− ·4	− ·6	−1·0	0·0	− ·3	+ ·1	+ ·6
...	+ ·4	+3·2	0·0	− ·2	− ·9	+ ·5	−1·9	−2·3	− ·3	− ·6	+ ·1	+2·0
...	+1·2	+1·1	+ ·2	− ·4	− ·9	− ·8	− ·4	−1·7	− ·2	− ·4	+ ·1	+2·2

Eastern District, 1860–69.

...	...	...	...	...	...	...	...	...	...	...	...	...
7	9·6	6·6	6·9	5·8−	6·8	6·6	7·6	10·9	9·8	11·1+	8·8	9·5
16	10·1	7·4	7·3	5·6−	6·4	6·4	7·5	10·2	9·6	10·9+	9·1	9·5
11	10·8	7·7	7·4	5·6	5·6−	6·4	6·7	9·9	9·4	11·3+	8·4	10·8
6	12·4+	7·8	7·0	5·3−	5·6	6·4	7·4	9·9	8·9	11·2	8·0	10·1
3	13·1+	9·3	7·1	5·1−	5·3	6·3	7·9	10·1	8·4	9·8	7·4	10·2
1	12·7+	9·7	7·6	5·0	4·7−	6·3	6·4	9·9	8·6	10·2	7·9	11·0
...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...
2	13·1+	9·2	6·8	5·8	4·1−	6·3	5·6	9·4	9·2	9·9	8·2	12·4
Mean ...	11·7	8·2	7·2	5·5	5·5	6·4	7·0	10·0	9·1	10·6	8·3	10·5

group from the mean of the district.

...	...	...	...	...	...	...	...	...	...	...	...	...
...	−2·1	−1·6	− ·3	+ ·3	+1·3	+ ·2	+ ·6	+ ·9	+ ·7	+ ·5	+ ·5	−1·0
...	−1·6	− ·8	+ ·1	+ ·1	+ ·9	0·0	+ ·5	+ ·2	+ ·5	+ ·3	+ ·8	−1·0
...	− ·9	− ·5	+ ·2	+ ·1	+ ·1	0·0	− ·3	− ·1	+ ·3	+ ·7	+ ·1	+ ·3
...	+ ·7	− ·4	− ·2	− ·2	+ ·1	0·0	+ ·4	− ·1	− ·2	+ ·6	− ·3	− ·4
...	+1·4	+1·1	− ·1	− ·4	− ·2	− ·1	+ ·9	+ ·1	− ·7	− ·8	− ·9	− ·3
...	+1·0	+1·5	+ ·4	− ·5	− ·8	− ·1	− ·6	− ·1	− ·5	− ·4	− ·4	+ ·5
...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...
...	+1·4	+1·0	− ·4	+ ·3	−1·4	− ·1	−1·4	− ·6	+ ·1	− ·7	− ·1	+1·9

TABLE II.

IRELAND.

Mean Annual Fall. Between	No. of Stations.	Western District, 1850–59. Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
in. in.													
30–35	...	...	...	...	...	...	...	...	...	...	...	...	...
35–40	3	11·2+	6·9	6·8	7·5	6·3−	8·4	8·2	8·9	7·4	9·2	8·6	10·6
40–45	...	...	...	...	...	...	...	...	...	...	...	...	...
45–50	...	...	...	...	...	...	...	...	...	...	...	...	...
Mean...	...	11·2	6·9	6·8	7·5	6·3	8·4	8·2	8·9	7·4	9·2	8·6	10·6

Departure of mean percentage for each

30–35	...	...	...	...	...	...	...	...	...	...	...	...	...
35–40	...	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
40–45	...	...	...	...	...	...	...	...	...	...	...	...	...
45–50	...	...	...	...	...	...	...	...	...	...	...	...	...

Eastern District, 1850–59.

20–25	2	9·3	5·5−	6·2	7·9	8·1	10·3+	9·0	8·4	8·0	9·6	9·7	8·0
25–30	2	9·8	5·3−	6·0	8·8	8·0	9·8+	9·6	7·7	7·9	9·6	8·7	8·8
30–35	2	11·5+	8·0	6·7	8·1	6·0−	7·7	8·5	9·2	7·2	8·5	8·4	10·2
35–40	...	...	...	...	...	...	...	...	...	...	...	...	...
40–45	...	...	...	...	...	...	...	...	...	...	...	...	...
Mean...	...	10·2	6·3	6·3	8·3	7·4	9·3	9·0	8·4	7·7	9·2	8·9	9·0

Departure of mean percentage for each

20–25	...	− ·9	− ·8	− ·1	− ·4	+ ·7	+1·0	0·0	0·0	+ ·3	+ ·4	+ ·8	−1·0
25–30	...	− ·4	−1·0	− ·3	+ ·5	+ ·6	+ ·5	+ ·6	− ·7	+ ·2	+ ·4	− ·2	− ·2
30–35	...	+1·3	+1·7	+ ·4	− ·2	−1·4	−1·6	− ·5	+ ·8	− ·5	− ·7	− ·5	+1·2
35–40	...	...	...	...	...	...	...	...	...	...	...	...	...
40–45	...	...	...	...	...	...	...	...	...	...	...	...	...

(*continued*).

IRELAND.

No. of Stations.	Western District, 1860–69.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	13·2+	5·7	9·3	5·1−	7·3	5·7	5·3	8·6	8·4	9·4	9·5	12·5
...	...	...	...	...	...	...	...	...	...	...	...	...
2	12·7+	6·2	8·7	5·5−	6·2	6·2	6·8	9·1	8·6	9·3	9·4	11·3
1	10·2+	8·1	8·8	6·0−	6·9	6·7	6·1	9·6	9·7	10·0	9·1	8·8
Mean...	12·0	6·7	8·9	5·5	6·8	6·2	6·1	9·1	8·9	9·6	9·3	10·9

group from the mean of the district.

...	+1·2	−1·0	+ ·4	− ·4	+ ·5	− ·5	− ·8	− ·5	− ·5	− ·2	+ ·2	+1·6
...	...	...	...	...	...	...	...	...	...	...	...	...
...	+ ·7	− ·5	− ·2	0·0	− ·6	0·0	+ ·7	0·0	− ·3	− ·3	+ ·1	+ ·4
...	−1·8	+1·4	− ·1	+ ·5	+ ·1	+ ·5	0·0	+ ·5	+ ·8	+ ·4	− ·2	−2·1

Eastern District 1860–69.

...	...	...	...	...	...	...	...	...	...	...	...	...
2	10·4+	5·8	9·0	5·7−	8·2	7·6	6·5	9·9	8·8	10·4+	8·4	9·3
1	11·0+	7·2	9·1	6·2−	7·3	6·5	6·7	9·9	7·8	10·2	9·4	8·7
2	10·5	6·7	8·7	5·8−	7·7	7·0	7·3	9·8	8·2	10·7+	8·7	8·9
1	13·0+	7·6	9·7	5·0−	6·9	7·1	5·6	7·8	7·4	10·8	8·3	10·8
Mean...	11·2	6·8	9·1	5·7	7·5	7·1	6·5	9·4	8·1	10·5	8·7	9·4

group from the mean of the district.

...	...	...	...	...	...	...	...	...	...	...	...	...
...	− ·8	−1·0	− ·1	0·0	+ ·7	+ ·5	0·0	+ ·5	+ ·7	− ·1	− ·3	− ·1
...	− ·2	+ ·4	0·0	+ ·5	− ·2	− ·6	+ ·2	+ ·5	− ·3	− ·3	+ ·7	− ·7
...	− ·7	− ·1	− ·4	+ ·1	+ ·2	− ·1	+ ·8	+ ·4	+ ·1	+ ·2	0·0	− ·5
...	+1·8	+ ·8	+ ·6	− ·7	− ·6	0·0	− ·9	−1·6	− ·7	+ ·3	− ·4	+1·4

TABLE III.—MONTHS IN WHICH THE MAXIMUM

			Mean Annual Fall	15–20.	20–25.	25–30.	30–35.	35–40.	40–45.	45–50.	50–55.	55–60.
Maxima.	England.	1850–59	Western ...	....	Oct. ...	Oct. ...	Oct. ...	Oct. ...	Jan. ...	Aug. Oct.	Jan. ...	Jan. ..
			Central ...	August	Oct. ...	Oct.						
			Eastern ...	July...	Oct. ...	Oct. ...	Oct. ...	Oct.				
		1860–69	Western ...	Sept. ..	August	Sept. .	Oct. ..	Oct. ...	Jan. ...	Oct.	Dec. ...	Dec. ...
			Central ...	August	August	Sept. ..	Sept. ..	....	Oct. ...	Oct.	Oct.	
			Eastern ...	August	August	Oct. ...	Oct. ...	Oct. ...	....	....	Jan.	
	Scotland.	1850–59	Western ...	....	Dec. ...	Jan. ...	Dec. ...	Dec. ...	Jan. ...	Dec.	Dec. ...	....
			Eastern ...	Oct. ...	Oct. ...	Oct. ...	Jan. ..	Jan. ...	Dec.			
		1860–69	Western ...	....	....	Jan. ...	Oct. ..	Oct. ...	Jan. ...	Jan.	Jan. ...	Jan.
			Eastern ...	....	Oct. ...	Oct. ...	Oct. ..	Jan.	Jan. ..	Jan.	....	....
	Ireland.	1850–59	Western ...	....	....	....	....	Jan.				
			Eastern ...	....	June ..	June ..	Jan.					
		1860–69	Western ...	....	....	....	Jan. ...	....	Jan. ...	J		
			Eastern ...	....	....	Jan. Oct.	Jan. ...	Oct. ...	Jan.			
Minima.	England.	1850–59	Western ...	....	Feb. ..	Feb. ...	March	May ...	May ...	May	May ...	May ...
			Central ...	Feb. ...	Feb. ...	Feb.						
			Eastern ...	Feb. ...	Feb. ...	Feb. ...	Feb. ...	Feb.				
		1860–69	Western ...	April .	April .	April .	April .	April .	April .	April	April .	April .
			Central ...	April .	April .	April .	April .	....	April .	April ,...	April.	
			Eastern ...	April .	April .	April .	April .	April .	....	....	July.	
	Scotland.	1850–59	Western ...	....	May ...	April .	May ...	May ...	May ...	May	May ...	....
			Eastern ...	March	May ...	May ...	May ...	May ...	April.			
		1860–69	Western ...	....	....	June ..	April .	June ..	May ...	June	May ...	May ...
			Eastern ...	....	April .	April .	May ...	April .	April .	May	....	....
	Ireland.	1850–59	Western ...	....	....	....	....	M				
			Eastern ...	....	Feb. ...	Feb. ...	May.					
		1860–69	Western ...	....	....	....	April .	....	April .	Ap		
			Eastern ...	....	....	April .	April .	April .	April.			

AND MINIMUM RAINFALL USUALLY OCCUR.

60–65.	65–70.	70–75.	75–80.	80–85.	85–90.	90–95.	95–100.	100–105.	125–130.	150–155.
Jan. ...	....	Jan. ...	....	....	....	....	....	....	Jan.	
Jan. ...	....	....	....	....	....	....	....	....	....	Dec.
....	Dec. ...	Dec.								
Dec. ... Jan.	Dec. ...	Dec. ...	Dec. ...	Dec. ...	....	....	....	Dec.		
May ...	....	May ...	....	....	....	....	....	....	May.	
May ...	....	....	....	....	....	....	....	....	....	May.
....	May ...	May.								
June .. May.	May ...	April .	May ...	July ...	....	....	....	May.		

TABLE IV.—ABSTRACT OF TABLE III.

				Jan.	Feb.	M	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Maxima.	1850–59.	England.	Western ...	6	...	...	...	...	...	...	1	...	5	...	...	12
			Central ...	...	...	...	...	...	...	...	1	...	2	...	...	3
			Eastern ...	...	...	...	...	...	...	1	...	...	4	...	...	5
		Scotland.	Western ...	2	...	...	...	...	...	...	...	...	...	...	7	9
			Eastern ...	2	...	...	...	...	...	...	...	...	3	...	1	6
		Ireland.	Western ...	1	...	...	...	...	...	...	...	...	...	...	...	1
			Eastern ...	1	...	...	...	...	2	...	...	...	...	...	...	3
			Per cent ...	30·8	...	...	...	...	5·1	2·6	5·1	...	35·8	...	20·6	39
	1860–69.	England.	Western ...	2	...	...	...	...	...	...	1	2	3	...	3	11
			Central ...	...	...	...	...	...	...	...	2	2	3	...	...	7
			Eastern ...	1	...	...	...	...	...	...	2	...	3	...	...	6
		Scotland.	Western ...	5	...	...	...	...	...	...	...	...	2	...	6	13
			Eastern ...	4	...	...	...	...	...	...	...	...	3	...	...	7
		Ireland.	Western ...	3	...	...	...	...	...	...	...	...	...	...	...	3
			Eastern ...	3	...	...	...	...	...	...	...	...	2	...	...	5
			Per cent ...	34·7	...	...	...	...	...	...	9·6	7·7	30·8	...	17·2	52

Owing to double maxima occurring in the Western District of England in the group with mean rainfall 45–50 in. in 1850–59, and in the Eastern District of Ireland with mean rainfall 25–30 in. in 1860–69, it will be found that there are 91 entries of maxima against 89 of minima.

TABLE IV. (*continued*).

Minima.			Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1850–59.	England.	Western ...	...	2	1	...	8	...	...	...	...	...	...	...	11
		Central ...	...	3	...	...	...	...	...	...	...	...	...	...	3
		Eastern ...	...	5	...	...	...	...	...	...	...	...	...	...	5
	Scotland.	Western ...	...	...	...	1	8	...	...	...	...	...	...	...	9
		Eastern ...	...	...	1	1	4	...	...	...	...	...	...	...	6
	Ireland.	Western ...	...	...	...	...	1	...	...	...	...	...	...	...	1
		Eastern ...	...	2	...	...	1	...	...	...	...	...	...	...	3
		Per cent ...	...	31·5	5·3	5·3	57·9								38
1860–69.	England.	Western ...	...	...	...	9	2	...	...	...	...	...	...	...	11
		Central ...	...	...	...	7	...	...	...	...	...	...	...	...	7
		Eastern ...	...	...	...	5	...	...	1	...	...	...	...	...	6
	Scotland.	Western ...	...	...	...	2	6	4	1	...	...	...	...	...	13
		Eastern ...	...	...	...	4	3	...	...	...	...	...	...	...	7
	Ireland.	Western ...	...	...	...	3	...	...	...	...	...	...	...	...	3
		Eastern ...	...	...	...	4	...	...	...	...	...	...	...	...	4
		Per cent ...	...	...	...	66·8	21·6	7·8	3·8						51

Owing to double maxima occurring in the Western District of England in the group with mean rainfall 45–50 in. in 1850–59, and in the Eastern District of Ireland with mean rainfall 25–30 in. in 1860–69, it will be found that there are 91 entries of maxima against 89 of minima.

TABLE V.—Comparison of Percentages in different Decades.

Name of Station and County.	Decennial period.	Mean Annual Fall in the period.	Monthly percentage of Annual Fall.											
			Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		in.												
Radcliffe Observatory, Oxford..	1820–29	21·721	5·3	5·3	5·1—	9·1	6·7	6·8	9·0	10·4	11·9	12·0+	9·0	9·4
	1830–39	23·561	5·5—	7·1	5·8	6·5	6·2	9·4	11·1	9·3	11·5+	10·2	10·4	7·0
	1840–49	23·549	7·2	7·0	5·5—	6·3	8·4	8·2	7·8	9·9	11·2	11·9+	9·9	6·7
	1850–59	22·241	8·8	4·1—	4·7	7·0	8·6	10·6	12·4+	10·1	9·0	11·5	7·1	6·1
Mean of 40 years		22·768	6·7	5·9	5·3	7·2	7·5	8·7	10·1	9·9	10·9	11·4	9·1	7·3
Epping, Essex	1830–39	25·839	6·5	8·3	6·1	6·1	5·5—	9·6	8·3	9·7	10·7+	10·3	10·4	8·5
	1840–49	26·986	8·2	6·7	6·2	5·5—	8·5	7·3	8·7	8·7	9·7	13·7+	10·3	6·5
	1850–59	23·184	8·7	4·5—	5·2	7·1	8·8	7·9	12·0	9·2	9·4	13·2+	8·5	5·5
	1860–69	24·132	8·9	6·2	7·4	5·3—	9·4	10·6+	6·8	10·0	10·3	9·3	7·7	8·1
Mean of 40 years		25·035	8·1	6·4	6·2	6·0	8·1	8·8	9·0	9·4	10·0	11·6	9·2	7·2
West Street, Tavistock, Devon..	1830–39	52·805	7·1	9·8	7·3	5·7	4·8—	8·1	6·9	7·2	8·6	10·6	12·8+	11·1
	1840–49	54·265	10·0	8·6	6·6	6·1—	6·3	6·9	7·0	8·0	8·1	10·9	12·1+	9·4
	1850–59	49·182	12·2+	5·6—	7·3	6·9	6·6	8·0	6·7	7·6	8·1	11·0	9·6	10·4
	1860–69	53·170	12·9+	7·2	7·8	4·5—	6·4	6·6	5·9	8·0	10·1	10·1	9·2	11·3
Mean of 40 years		52·356	10·6	7·8	7·2	5·8	6·0	7·4	6·6	7·7	8·7	10·7	10·9	10·6
Exeter Institution, Devon	1820–29	29·904	7·7	6·4	7·2	7·9	7·0	6·1—	8·1	7·0	9·9	13·2+	9·1	10·4
	1830–39	28·920	7·4	8·8	6·3	6·2	4·8—	9·4	6·3	7·3	8·0	10·5	15·0+	10·0
	1840–49	29·347	10·4	7·5	6·9	6·9	7·2	5·8	5·8—	7·8	8·6	11·2	13·2+	8·7
	1850–59	26·912	9·1	5·2—	6·3	9·1	7·2	8·2	7·2	7·8	7·7	12·4+	10·0	9·8
	1860–69	31·757	11·8+	6·6	10·2	5·0—	8·0	6·5	5·1	7·3	9·3	10·6	8·4	11·2
Mean of 50 years		29·368	9·3	6·9	7·4	7·0	6·8	7·2	6·5	7·4	8·7	11·6	11·2	10·0

Exeter, St. Thomas, Devon......	1820–29	33·665	8·5	6·9	7·4	8·0	6·6	5·5−	7·3	6·3	9·3	13·4+	9·5	11·3
	1830–39	33·517	8·0	9·1	6·9	6·1	5·0−	8·8	6·2	7·1	7·7	10·4	14·7+	10·0
	1840–49	33·246	10·8	8·2	6·6	7·0	6·5	5·4−	6·1	7·2	8·4	11·4	13·1+	9·3
	1850–59	31·154	9·8	6·2−	6·7	8·6	7·1	7·5	7·1	6·7	7·8	12·1+	9·6	10·8
Mean of 40 years		32·646	9·3	7·6	6·9	7·4	6·3	6·8	6·7	6·8	8·3	11·8	11·7	10·4
Lyndon, Rutland	1740–49	18·533	7·2	4·2−	7·2	6·7	6·5	11·9	12·2+	7·1	9·3	9·5	10·1	8·1
	1750–59	21·493	7·9	4·8−	7·0	9·6	7·3	9·6	13·8+	11·9	5·6	6·4	7·3	8·8
	1760–69	22·245	7·3	8·2	4·5−	5·1	7·2	11·6	10·7	10·1	8·3	11·8+	7·9	7·3
	1770–79	26·876	6·2	6·6	5·3	4·6−	7·9	9·1	9·4	9·9	10·9	11·1	11·2+	7·8
	1780–89	23·848	7·6	5·8	4·6−	7·5	9·6	9·7	11·8	8·6	11·9+	9·2	6·8	6·9
Mean of 50 years		22·599	7·2	5·9	5·7	6·7	7·7	10·4	11·6	9·5	9·2	9·6	8·7	7·8
Manchester, Lancashire	1800–09	31·693	8·0	6·7	5·4−	5·7	7·1	6·6	8·7	8·4	10·7	10·7	10·5	11·5+
	1810–19	35·621	6·8	8·4	8·0	5·0−	7·7	7·1	10·4	8·4	6·3	11·5+	9·8	10·6
	1820–29	38·407	5·1−	5·5	7·2	6·6	6·8	6·2	10·9+	10·8	9·3	10·6	10·7	10·3
	1830–39	36·908	6·0	6·9	7·1	6·2	4·6−	10·8	10·6	8·9	9·3	9·5	11·4+	8·7
Mean of 40 years		35·657	6·5	6·9	6·9	5·9	6·5	7·7	10·1	9·1	8·9	10·6	10·6	10·3
Well Head, Halifax, Yorkshire	1830–39	34·514	7·0	8·7	7·1	6·0	5·4−	10·6	9·1	8·1	8·4	9·6	11·3+	8·7
	1840–49	31·883	9·7	6·3	7·1	6·1−	7·4	7·9	8·8	9·8	8·1	12·3+	9·4	7·1
	1850–59	30·713	9·1	6·4	5·8	6·4	5·5−	10·4	9·4	11·4+	8·6	10·8	7·6	8·6
	1860–69	33·313	8·8	9·2	8·4	5·2−	7·1	5·6	6·8	8·6	10·0	10·8+	9·2	10·3
Mean of 40 years		32·606	8·6	7·7	7·1	5·9	6·3	8·6	8·5	9·5	8·8	10·9	9·4	8·7
Kendal, Westmoreland...........	1810–19	50·189	7·0	10·8	9·5	4·9−	6·8	5·9	7·4	7·4	8·1	11·1	9·7	11·4+
	1820–29	55·107	7·1	7·9	7·8	5·2−	5·4	5·3	7·4	10·3	9·3	10·7	11·8+	11·8
	1830–39	56·219	7·2	9·4	8·1	4·5	2·9−	8·2	9·5	8·1	9·5	10·2	11·5+	10·9
	1840–49	51·176	9·9	7·3	7·2	5·3	5·3−	7·0	9·5	·09	7·1	11·7+	11·2	9·5
	1850–59	44·912	12·1+	8·6	5·6	5·3	4·9−	8·3	8·2	10·6	7·8	9·4	8·2	11·0
	1860–69	53·322	10·9+	9·0	7·5	5·5	5·5	6·1	5·3−	9·6	10·5	10·1	9·4	10·6
Mean of 60 years		51·821	9·0	8·8	7·6	5·1	5·1	6·8	7·9	9·2	8·7	10·6	10·3	10·9

TABLE V. (*continued*).

Name of Station and County.	Decennial period.	Mean Annual Fall in the period.	Monthly percentage of Annual Fall.											
			Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		in.												
Inchkeith	1820–29	21·219	7·6	5·7	5·6–	7·2	7·7	5·6	10·5	13·0+	6·6	10·1	10·0	10·4
	1830–39	25·151	5·7	6·6	7·2	5·3	5·3–	10·9	10·6	11·0	12·7+	7·8	8·6	8·3
	1840–49	24·415	6·7	7·8	5·7	5·2–	8·8	9·7	10·8	10·8	7·5	11·9+	8·5	6·6
	1850–59	21·453	8·6	6·6	5·3	5·2–	6·7	11·2	10·7	12·4+	8·3	9·2	7·4	8·4
Mean of 40 years		23·060	7·2	6·7	5·9	5·7	7·1	9·4	10·6	11·8	8·8	9·8	8·6	8·4
Mount Stuart, Bute	1800–09	47·021	11·5+	8·4	6·5	6·0	7·0	4·6–	7·5	10·4	7·6	10·8	9·3	10·4
	1810–19	52·728	9·2	10·2	8·4	4·6–	5·9	6·7	7·1	8·0	7·8	10·7	10·0	11·4+
	1820–29	45·202	7·6	7·4	8·6	5·6	5·0	3·9–	6·8	9·9	8·7	11·7	12·6+	12·2
	1830–39	48·276	6·9	8·3	9·1	4·9	4·7–	6·3	8·0	8·4	10·9	10·7	10·8	11·0+
Mean of 40 years		48·307	8·8	8·6	8·1	5·3	5·6	5·4	7·4	9·2	8·7	11·0	10·7	11·2
Rhinns of Islay, Argyll	1830–39	34·068	7·2	8·2	8·1	4·6	3·7–	7·0	8·3	8·8	10·6	9·6	13·0+	10·9
	1840–49	33·790	10·1	7·7	6·5	5·9	5·2–	7·0	9·8	8·0	7·9	12·8+	10·8	8·3
	1850–59	30·581	11·7+	7·6	5·9	6·8	4·7–	6·8	8·8	9·2	7·8	11·0	8·6	11·1
	1860–69	33·434	9·2	8·0	7·7	5·3–	6·0	5·5	6·0	10·6	9·2	11·4+	11·2	9·9
Mean of 40 years		32·968	9·5	7·9	7·1	5·6	4·9	6·6	8·2	9·2	8·9	11·2	10·9	10·0
Isle of May, Fife	1820–29	19·998	7·8	5·6	5·0–	7·1	6·7	5·7	10·4	13·0+	7·3	10·6	9·7	11·1
	1830–39	21·963	6·0	6·2	6·4	5·9	5·7–	11·1	10·6	11·4	11·9+	8·2	8·8	7·8
	1840–49	20·940	7·5	6·9	5·4	5·2–	8·5	10·5	12·3+	10·2	8·1	11·2	8·7	5·5
	1850–59	15·213	7·5	6·0	5·5–	6·4	6·1	8·0	7·7	12·8+	8·4	11·3	10·4	9·9
	1860–69	20·482	9·6	6·1	4·9–	6·4	8·2	7·6	8·1	11·6+	10·5	10·8	7·4	8·8
Mean of 50 years		19·719	7·7	6·2	5·5	6·2	7·0	8·6	9·8	11·8	9·2	10·4	9·0	8·6

Buchanness, Aberdeen	1830–39	26·396	6·7	5·9	7·2	6·9	5·9—	8·6	8·4	8·6	11·3+	10·1	10·8	9·6
	1840–49	26·842	9·2	7·8	5·7	5·8	5·6—	7·3	9·3	9·9	8·2	12·3+	9·7	9·2
	1850–59	23·398	10·0	6·6	6·2	7·7	4·7—	7·9	8·4	8·4	7·9	11·7+	11·3	9·2
	1860–69	25·588	9·7	7·1	7·9	6·2	6·6	5·9—	6·0	9·9	10·0	10·4	9·2	11·1+
Mean of 40 years		25·556	8·9	6·8	6·8	6·7	5·7	7·4	8·0	9·2	9·3	11·1	10·3	9·8
Kinnaird Head, Aberdeen	1820–29	19·620	8·8	6·0	5·6	7·7	5·3—	6·4	8·0	11·0	6·4	13·1+	11·7	10·0
	1830–39	19·664	4·6	4·5—	6·6	6·9	5·7	8·3	8·9	9·5	12·9+	11·3	12·0	8·8
	1840–49	22·011	7·7	6·2	5·2—	5·5	5·8	9·4	10·0	10·5	8·3	13·2+	10·4	7·8
	1850–59	22·045	8·9	5·8	4·9	7·5	4·6—	7·4	8·6	8·4	8·8	14·4+	10·8	9·9
	1860–69	24·168	7·7	7·8	6·5	5·7	5·6	5·0—	7·0	11·4+	11·1	11·0	11·2	10·0
Mean of 50 years		21·502	7·5	6·1	5·8	6·6	5·4	7·3	8·5	10·2	9·5	12·6	11·2	9·3
Island Glass, Inverness W.	1830–39	33·228	7·0	8·3	8·0	6·3	4·2—	6·5	7·4	8·5	10·9	11·3	11·9+	9·7
	1840–49	34·980	9·7	6·9	7·1	5·5	4·9—	7·3	7·6	9·5	8·6	10·8	12·1+	10·0
	1850–59	31·916	10·6	9·4	7·1	5·3	4·1—	7·6	9·3	7·0	7·9	9·6	10·6	11·5+
	1860–69	31·129	8·7	10·0	7·3	5·7	5·5—	5·9	5·8	11·1+	10·5	9·8	9·7	10·0
Mean of 40 years		32·813	9·0	8·6	7·4	5·7	4·7	6·8	7·5	9·0	9·5	10·4	11·1	10·3
Start Point, Orkney	1830–39	27·394	8·4	7·8	8·8	6·5	4·1—	4·6	5·7	6·7	9·4	13·0	13·3+	11·7
	1840–49	25·052	11·7	8·0	7·0	5·3	4·6—	5·6	6·7	8·8	7·2	13·1+	11·3	10·7
	1850–59	23·767	12·2	7·2	5·8	5·2	4·0—	6·3	8·3	7·7	7·2	15·8+	10·1	10·2
	1860–69	31·371	9·3	7·9	7·8	6·0	5·2	3·8—	4·9	10·2	9·6	13·0+	9·9	12·4
Mean of 40 years		26·896	10·4	7·7	7·4	5·7	4·5	5·1	6·4	8·4	8·3	13·7	11·1	11·3

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Above sea-level.
	1870.					ft. in.	feet.
425.	Sept. 21.	CHESHIRE. Bidstone Observatory, *MERSEY HARBOUR BOARD.* *J. Hartnup, Esq.*	X.	Negretti & Zambra	9 a.m.	0 6	182
426.	Sept. 21.	CHESHIRE. Bidstone Observatory, *MERSEY HARBOUR BOARD.* *J. Hartnup, Esq.*	I.	Adie	monthly.	0 8	182
427.	Sept. 22.	DERBYSHIRE. Willersly Gardens, Matlock. *P. ARKWRIGHT, ESQ.* *Mr. Tissington.*	III.	Horne & Thornethwaite.	9 a.m.	1 0	440
428.	Sept. 22.	DERBYSHIRE. Matlock Bath. *R. CHADWICK, ESQ.* *R. Chadwick, Esq.*	III.	Anon...............	......	2 0	500
429.	Sept. 26.	DERBYSHIRE. Alderwasly Hall. *A. F. HURST, ESQ.* *Mr. Greenwood.*	III.	Anon...............	9 a.m. preceding.	5 0	530
430.	Sept. 27.	DERBYSHIRE. Stancliffe Hall. *SIR J. WHITWORTH, F.R.S.* *Mr. Dawson.*	III.	Anon...............	monthly.	1 6	488
431.	Sept. 30.	DERBYSHIRE. Axe Edge. *E. J. SYKES, ESQ.* *E. J. Sykes, Esq.*	X.	Casella	1st each month.	1 0	1620
432.	Sept. 30.	DERBYSHIRE. Devonshire Hospital, Buxton. *E. J. SYKES, ESQ.* *E. J. Sykes, Esq.*	X.	Casella	9 a.m.	5 0	1005
433.	Sept. 30.	DERBYSHIRE. Devonshire Hospital. *E. J. SYKES, ESQ.* *E. J. Sykes, Esq.*	VIII.	Marshall	......	......	......
434.	Oct. 4.	DERBYSHIRE. Chatsworth, The Gardens. *THE DUKE OF DEVONSHIRE.* *Mr. Speed.*	VIII.	Marshall	9 a.m.	6 3	404
435.	Oct. 4.	DERBYSHIRE. Stoney Middleton. *REV. URBAN SMITH.* *Rev. Urban Smith.*	III.	Anon...............	9 a.m.	4 0	692

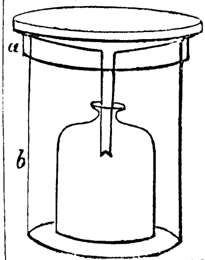
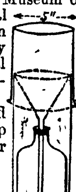
RAIN-GAUGES (*continued from Brit. Assoc. Rep.* 1870, p. 228).

Diameters (that marked M = mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
7·99	·1	1260	+·001	S.W. Observatory 30°.	Good position on the side of Bidston Hill, near summit, and N.E. of the Observatory.	425.
8·02	·2	2520	+·002			
8·00	·3	3755	+·004			
8·00	·4	5050	+·003			
M 8·003	·5	6320	+·003			
3·32				Observatory Dome S.W. 30°.	Close to No. 425. Testing not completed, but measuring-scale correct, and cylinder believed to be true.	426.
3·35						
3·35						
3·34						
M 3·340						
5·98	·1	680	+·005		In kitchen garden, clear open space, ground level for some distance.	427.
6·00	·2	1390	+·006			
6·02	·3	2100	+·006			
6·02	·4	2830	+·004			
M 6·005	·5	3580	+·010			
5·05	·1	480	+·003	Clear from W through S. to E. Trees E. by N. to W. 75°.	This station is on the N. side of the hill known as the Heights of Abraham; the garden and grounds rise in rapid terraces and are thickly wooded. I could not see any better position.	428.
4·94	·2	970	+·004			
4·98	·3	1470	+·003			
5·02	·4	1950	+·006			
M 4·998	·5	2460	+·003			
5·01	·1	480	+·003	S. Apple 30°.	In garden west of the hall.	429.
5·00	·2	960	+·006			
5·00	·3	1460	+·005			
4·99	·35	1700	+·007			
M 5·000						
5·02	·1	490	+·001	Quite clear.	This gauge was fixed in a wooden frame which surrounded the funnel, and was not sufficiently below it to be free from liability to produce insplashing. I left instructions that it should be lowered 4 inches. On large lawn N.W. of Hall.	430.
4·98	·2	970	+·004			
5·00	·3	1475	+·002			
5·00	·4	1970	+·003			
M 5·000	·5	2465	+·003			
7·93	·1	1320	−·004	Quite clear.	On the level surface of the moor, about 600 feet above Buxton, and 3 miles S.W. of it. The position is extremely exposed.	431.
8·04	·2	2570	−·003			
8·00	·3	3760	+·003			
8·00	·4	5050	+·001			
M 7·993	·5	6340	correct.			
7·93	·1	1320	−·004	Hospital N.W. 26°. Clear in all other directions.	On dwarf post in an open part of the Hospital grounds, near the centre of Buxton. Position good, and gauge in good order.	432.
8·03	·2	2570	−·003			
8·00	·3	3760	+·003			
7·99	·4	5050	+·001			
M 7·988	·5	6340	−·001			
	·1	1240			An old gauge, out of order at date of inspection, but subsequently repaired and used at Poole's Cavern, Buxton.	433.
	·2	2500				
	·25	3100				
8·00	·1	1240	+·003	Quite open.	On post in kitchen garden. This gauge was examined 1865, Sept. 21 (No. 123); but as the glass was not initialled, and the funnel had been rendered more nearly circular, I retested it. I find on comparison that of the five scale-points two errors are absolutely identical; one differs by 0·001 in., one by 0·002, and one by 0·004 in.	434
8·03	·2	2500	+·004			
8·00	·3	3750	+·005			
8·00	·4	4960	+·010			
M 8·008	·5	6250	+·009			
5·03	·1	480	+·003	....	On the top of dwarf stand in garden, which slopes from W. to E., and has a wall running N.N.W.-S.S.E., at about 8 ft. from the gauge. Mr. Smith states that his place is so exposed and windy that this partial shelter is beneficial, which seems probable.	435.
4·98	·2	970	+·004			
5·02	·3	1470	+·004			
4·98	·4	1970	+·003			
M 5·002	·5	2470	+·002			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Above sea-level.
						ft. in.	feet.
436.	1870. Oct. 11.	MIDDLESEX. Camden Square. *G. J. SYMONS, Esq.* *G. J. Symons, Esq.*	VI.	Crosley	9 a.m. 1st	4 0	115
437.	1871. Aug. 10.	EDINBURGH. Dalkeith Gardens. *DUKE OF BUCCLEUCH.* *Mr. Dunn.*	I.	Bryson	9 a.m.	0 6	183
438.	Aug. 17.	PERTHSHIRE. Bolfracks, Aberfeldy. *J. F. WYLLIE, ESQ.* *J. F. Wyllie, Esq.*	I.	Anon...............	1st each month.	0 6	....
439.	Aug. 23.	INVERNESS. Culloden House. *A. FORBES, ESQ.* *A. Forbes, Esq.*	IV.	Adie	8 a.m.	3 0	82
440.	Aug. 29.	YORKSHIRE. Scarborough Crystal Garden. *DR. FOX.* *Mr. Walsham.*	XII.	Casella	10 a.m.	1 0	102
441.	Aug. 30.	DURHAM. Darlington, Southend Gardens. *J. PEASE, ESQ.* *Mr. Richardson.*	X.	Negretti & Zambra	9 a.m.	0 0	140
442.	Aug. 30.	DURHAM. Darlington, Southend Gardens. *J. PEASE, ESQ.* *Mr. Richardson.*	XII.	Casella	9 a.m	0 8	140
443.	Aug. 30.	DURHAM. Darlington, Southend Gardens. *J. PEASE, ESQ.* *Mr. Richardson.*	See Fig.	Anon...............	9 a.m.	0 6	140
444.	Aug. 31.	YORKSHIRE. York, St. Mary's Abbey. *YORKSHIRE PHIL. SOC.* *Mr. Wakefield.*	VII.	Anon...............	10 a.m.	0 6	30
445.	Aug. 31.	YORKSHIRE. York Museum Roof. *YORKSHIRE PHIL. SOC.* *Mr. Wakefield.*	VII.	Anon...............	10 a.m.	43 6	73
446.	Sept. 1.	YORKSHIRE. Hawsker Garden, Whitby. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See fig.	Casella	9 a.m.	1 0	340

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
9·98	.1	2525	correct.	E.N.E. House 30°.	A second, or check-gauge, not found reliable, although accurate in construction.	436.
10·02	·2	5050	correct.			
10·00	·3	7570	correct.			
10·00	·4	10000	+·004			
M 10·000	·5	12500	+·005			
3·12	1·00	2000	+·021	W. Trees 38°.	This is not the *old* Dalkeith gauge, of which the fate is unknown, but a comparatively modern one, on a grass-plot, which at the above date had been allowed to grow too long; level ground and good position.	437.
3·15	1·55	3000	+·018	S.W. „ 22°.		
3·13	2·06	4000	+·033	S. „ 5°.		
3·16	2·58	5000	+·024			
M 3·140	3·09	[illegible]000	+·025			
13·00	4·61	9000	+·013		A very bad gauge, wofully out of order, very unsteady, not level, and so generally unsatisfactory, that it was not thought worth while to test its *precise* error.	438.
13·25						
13·25						
13·12						
M 13·155						
6·72	·125	1110	+·002	W.S.W. Apple 20°.	This position, though good, was not that which it was intended should eventually be occupied by the principal gauge at this station, as Mr. Forbes contemplated railing off a portion of the park expressly for meteorological apparatus.	439.
6·71	·192	1660	+·007	N.E. „ 32°.		
6·76	·243	2160	+·002			
6 71	·308	2660	+·012			
M 6·725						
4·98	·1	490	+·001	N. House 30°.	In nursery garden sloping to south. I urged that the gauge should be shifted a little to N.E. to get more away from the trees, which was agreed to.	440.
5·00	·2	980	+·002	S.W. Trees 43°.		
5·02	·3	1480	+·001			
4·98	·4	1980	correct.			
M 4·995	·5	2480	−·001			
8·00	·1	1250	+·001	N. Elm 40°.	Fair position, near the bottom of a rather flat valley.	441.
8·00	·234	3000	−·002	N.E. „ 28°.		
8·00	·4	5000	+·006	N.W. „ 33°.		
8·00	·5	6270	+·006			
M 8·000						
5·00	·1	505	−·003		Close to No. 441. This gauge has a very flat rim.	442.
4·98	·2	1020	−·008			
4·98	·3	1515	−·009			
4·93	·4	2010	−·010			
M 4·973	·5	2510	−·012			
8·04	·1	1250	+·004		Close to 441 and 442. This is an experimental gauge, of the remarkable pattern shown in the annexed figure. Funnel, 8 in. diameter, circular, rim vertical and ½ in. deep; funnel scarcely falling at all to centre, not more than ½ inch: *a*, a rim falling loosely over; *b*, a tin cylinder to keep funnel in place.	443.
8·10	·234	3000	+·002			
8·10	·4	5000	+·014			
8·08	·5	6270	+·016			
M 8·080						
10·09	·1	2600	correct.	S.W. Sycamore 44°.	Neither this nor the following gauge were regularly attended to at the time of this examination; but it was promised that they should be in future. The former was in an enclosed part of the ruins of St. Mary's Abbey, the latter on the roof of the Museum of the Yorkshire Philosophical Society — the position, in fact, occupied in 1836 by one of the experimental gauges used by Prof. Phillips.	444.
10·31	·2	5050	+·005			
9·98	·302	7575	+·011	N. Chestnut 46°.		
10·22	·39	10100	+·002			
M 10·150	·486	12625	−·005			
9·98	·1	2600	−·003	....		445.
10·05	·2	5050	correct.			
10·00	·302	7575	+·002			
9·97	·39	10100	−·010			
M 10·000	·48	12625	−·020			
5·00	·1	495	correct.	W. House 48°.	This guage was of unpainted sine, and had a 3-inch deep snow-collecting rim, as per sketch.	446.
5·01	·2	975	+·004	S.S.W. Trees 30°.		
5·00	·3	1460	+·005	S.S.E. Trees 25°.		
5·00	·4	1980	+·001	N. Trees 25°.		
M 5·003	·5	2460	+·004			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Abve sea-level.
	1871.					ft. in.	feet.
447.	Sept. 1.	YORKSHIRE. Hawsker Garden. *REV. F. W. STOW.* *Rev. F. W. Stow.*	IV.	....	9 a.m.	2 3	340
448.	Sept. 1.	YORKSHIRE. Hawsker Paddock. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See No. 446.	Casella	9 a.m.	1 0	335
449.	Sept. 1.	YORKSHIRE. Hawsker Paddock. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See No. 446.	Casella	Monthly.	1 0	335
450.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See No. 446.	Casella	9 a.m.	1 0	428
451.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *COLONEL WARD.* *Rev. F. W. Stow.*	III.	Casella	9 a.m.	1 0	428
452.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See Remarks.	Anon...............	9 a.m.	10 0	438
453.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See Remarks.	Anon...............	9 a.m.	10 0	438
454.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See Remarks.	Anon...............	9 a.m.	5 0	433
455.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *REV. F. W. STOW.* *Rev. F. W. Stow.*	XII.	Casella	9 a.m.	1 0	428
456.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *REV. F. W. STOW.* *Rev. F. W. Stow.*	X.	Casella	9 a.m.	1 0	428
457.	Sept. 1.	YORKSHIRE. Hawsker Exp. Field. *REV. F. W. STOW.* *Rev. F. W. Stow.*	See Remarks.	Anon...............	9 a.m.	1 0	428

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
11·86	·1	2850	correct.	....	This gauge was formerly used at Red Hall, near Leeds, and subsequently at the Knoll, Ripon. Its present position, near No. 446, was rather too sheltered.	447.
12·12	·2	5780	−·003			
12·00	·3	8568	correct.			
12·00	·4	11435	−·001			
M 11·995	·5	14280	−·001			
5·01	·1	495	correct.	All objects under 20°.	Similar to No 446, but in a more open position.	448.
5·00	·2	975	+·004			
5·01	·3	1460	+·006			
5·00	·4	1980	+·001			
M 5·005	·5	2460	+·005			
5·01	·1	495	correct.	....	Close to, and similar to No. 448; but read monthly instead of daily.	449.
4·98	·2	975	+·003			
5·01	·3	1460	+·005			
5·00	·4	1980	correct.			
M 5·000	·5	2460	+·004			
5·01	·1	495	correct.	....	Similar to No 446, except that the snow-funnel is 6 inches deep. This and the following gauges, Nos. 450 to 457 inclusive, were in a railed enclosure in a high and exposed field, along with a large number of previously tested gauges. A ground-plan of the arrangements, general view of the same, and detailed engravings of the instruments have been published in 'British Rainfall,' 1871.	450.
5·00	·2	975	+·003			
5·00	·3	1460	+·005			
4·99	·4	1980	correct.			
M 5·000	·5	2460	+·004			
1·00	·1	20	correct.			451.
1·00	·2	39	+·005			
1·01	·3	58	+·010			
1·01	·4	78	+·010			
M 1·005	·5	98	+·010			
3·00	·1	180	correct.	....	This and No. 453 formed the pair of gauges, the former with the orifice horizontal, and the latter with it vertical and rotated by a vane, for determining the angle of rain falling at 10 feet above the surface.	452.
3·00	·2	358	correct.			
3·01	·3	539	−·001			
3·00	·4	718	−·001			
M 3·003	·5	894	correct.			
3·00	·1	180	correct.			453.
2·99	·2	358	correct.			
3·02	·3	539	−·001			
3·00	·4	718	−·001			
M 3·003	·5	894	correct.			
3·02	·1	180	−·001	....	The vertical-mouthed portion of the two-mouthed gauge at 5 feet.	454.
2·98	·2	358	correct.			
3·00	·3	539	−·002			
3·00	·4	718	−·002			
M 3·000	·5	894	−·001			
3·00	·1	180	−·001			455.
3·00	·2	358	correct.			
3·00	·3	539	−·002			
3·00	·4	718	−·002			
M 3·000	·5	894	−·001			
8·00						456.
8·01	·2	2560	−·002			
8·00						
7·99	·4	5050	+·002			
M 8·000						
3·00	·1	180	−·001	....	The vertical-mouthed portion of the two-mouthed gauge at 1 ft.	457.
2·99	·2	358	correct.			
3·00	·3	539	−·002			
3·01	·4	718	−·002			
M 3·000	·5	894	−·001			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Above sea-level.
	1872.					ft. in.	feet.
458.	Aug. 19.	SUSSEX. Brighton, Goldstone Bottom.[1] *BRIGHTON CORPORATION.* *Mr. Barker.*	XII.	Casella	9 a.m. preceding.	0 10	140
459.	Aug. 20.	SUSSEX. Brighton, Buckingham Place. *F. E. SAWYER, ESQ.* *F. E. Sawyer, Esq.*	III.	Rowley	9 a.m. preceding.	1 2	200
460.	Aug. 24.	SUSSEX. Beachy Head. *MISS W. L. HALL.* *Miss W. L. Hall.*	XII.	Casella	....	1 6	530
461.	Aug. 24.	SUSSEX. Beachy Head. *MISS W. L. HALL.* *Miss W. L. Hall.*	XII.	Casella	....	1 6	530
462.	Aug. 26.	SUSSEX. Cemetery, Eastbourne. *MISS W. L. HALL.*	XII.	Casella	9 a.m. preceding.	4 0	170
463.	Aug. 27.	SUSSEX. Pevensey Road, Eastbourne. *MISS W. L. HALL.* *Miss W. L. Hall.*	XI.	Negretti & Zambra	10 a.m.	3 0	25
464.	Aug. 27.	SUSSEX. The Hollies, Hastings. *A. H. WOOD, ESQ.* *A. H. Wood, Esq.*	X.	Negretti & Zambra	9 a.m. preceding.	3 0	100
465.	Aug. 28.	SUSSEX. Wallsend Cottage, Pevensey. *M. VIDLER, ESQ.* *M. Vidler, Esq.*	X.	Negretti & Zambra	....	4 0	10
466.	Aug. 28.	SUSSEX. Pevensey Vicarage. *REV. H. BROWN.* *Rev. H. Brown.*	X.	Negretti & Zambra	9 a.m. preceding.	1 0	15
467.	Aug. 29.	SUSSEX. Court Farm, Falmer. *R. R. VERRALL, ESQ.* *R. R. Verrall, Esq.*	XII.	Anon...	Irregular.	3 6	312
468.	Sept. 9.	SUSSEX. Heron's Ghyll, Buxted. *C. PATMORE, ESQ.* *C. Patmore, Esq.*	X.	Negretti & Zambra	9 a.m. preceding.	1 0	405

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
4·98	·1	495	correct.	....	In a very open position on the N. corner of the reservoir-bank, entirely unsheltered.	458.
5·00	·2	990	correct.			
4·97	·3	1490	−·001			
5·02	·4	1970	−·002			
M 4·993	·5	2480	−·002			
4·98	·2	1000	−·002	S. Trees 62°.	Position not good, but the best available. In E. at a distance of a few feet, the ground falls precipitously to the yard of the railway-station.	459.
5·00	·3	1490	−·001	W. House 52°.		
4·99	·4	2000	−·004	N. Wall 13°.		
5·00	·5	2510	−·007	E. Wall 33°.		
M 4·993						
5·00	·1	500	−·001	....	At the time of visiting this and the following gauge they were near together, and in the position described in No. 194. Subsequently No. 461 has been removed further inland, in order to obtain a less exposed position and freedom from the updraught produced by the steep face of the cliff.	460.
4·98	·2	1000	−·002			
4·98	·3	1480	correct.			
5·00	·4	1980	−·001			
M 4·990	·5	2470	correct.			
4·99	·1	500	−·001	....		461.
5·01	·2	1000	−·002			
5·01	·3	1480	+·001			
4·99	·4	1980	+·001			
M 5·000	·5	2470	+·002			
5·00	·1	495	correct.	E.N.E. Beans 50°.	Gauge fixed on a post, in order to obtain better exposure. On pointing out the injurious effect of the beans they were removed.	462.
5·00	·2	995	−·001	N.W. Elder 20°.		
4·99	·3	1500	−·002	S. Chapel 10°.		
5·01	·4	1960	+·005			
M 5·000	·5	2480	correct.			
5·00	·1	500	−·001	S.W. Houses 36°.	See No. 196.	463.
5·00	·2	1000	−·002	N. Houses 48°.		
5·00	·3	1480	+·002			
5·01	·4	1980	+·001			
M 5·003	·5	2470	+·002			
8·00	·1	1300	−·002	S. Laurels 65°.	On a dwarf post in a bed of laurels, which had been cut away from time to time to secure sufficient exposure. On showing that this had not been obtained, observer agreed to remove the gauge to a thoroughly clear spot.	464.
8·01	·2	2570	−·002	E. Laurels 60°.		
8·02	·3	3810	correct.	W. Laurels 55°.		
7·98	·4	5100	−·002			
M 8·003	·5	6320	−·002			
7·98	·1	1300	−·003	....	See No. 193. It appears, from long-continued observation, that the extremely exposed position of this gauge prevents its indications being correct.	465.
8·01	·2	2550	−·002			
8·02	·3	3800	−·001			
7·93	·4	5050	+·001			
M 7·985	·5	6300	+·002			
8·01	·1	1260	+·001	S. House 45°.	In the garden of the Vicarage, and in the best position obtainable.	466.
7·99	·2	2490	+·004	E. Trees 60°.		
7·99	·3	3780	+·002	W. Trees 50°.		
8·00	·4	4990	+·007			
M 7·997	·5	6250	+·007			
5·00	·1	520	−·006	S. Houses 30°.	This gauge being very much in error, the observer at once decided on having a new one. This was specially desirable, for two reasons:—(1) because the locality is an important one; (2) because, in addition to the scale-error of the old gauge, the funnel did not rest firmly on the receiver.	467.
5·00	·2	1020	−·007	E. Trees 55°.		
4·99	·3	1530	−·011	W. Trees 48°.		
4·93	·4	2050	−·017			
M 4·980	·5	2550	−·018			
7·99	·1	1250	+·001	W.N.W. House 28°	Gauge temporarily placed on a terrace-walk. The above angles are for the position selected.	468.
8·00	·2	2570	−·002	N. Wall 32°.		
8·00	·3	3800	correct.	E. Firs 30°.		
8·00	·4	5050	+·002			
M 7·998	·5	6300	+·004			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Height of gauge. Above sea-level.
	1872.					ft. in.	feet.
469.	Sept. 9.	SUSSEX. Crowborough, Beacon Observatory. *C. L. PRINCE, ESQ., F.R.A.S.* *C. L. Prince, Esq., F.R.A.S.*	X.	Negretti & Zambra	9 a.m. preceding.	1 0	777
470.	Sept. 24.	NORFOLK. Bexwell Rectory. *REV. E. J. HOWMAN.* *Rev. E. J. Howman.*	XII.	Casella	9 a.m. preceding.	1 0	120
471.	Sept. 25.	NORFOLK. West Dereham. *REV. E. J. HOWMAN.* *Mr. C. Blanchfield.*	III.	Casella	9 a.m. preceding.	1 0	20
472.	Sept. 25.	NORFOLK. White House, Wereham. *F. R. H. MASON, ESQ.* *F. R. H. Mason, Esq.*	X.	Negretti & Zambra	9 a.m. preceding.	0 5	60
473.	Sept. 25.	NORFOLK. White House, Wereham. *F. R. H. MASON, ESQ.* *F. R. H. Mason, Esq.*	XI.	Negretti & Zambra	9 a.m. preceding.	6 0	66
474.	Sept. 25.	NORFOLK. Fincham Rectory. *REV. W. BLYTHE.* *Rev. W. Blythe.*	See fig. 2, Br Ass Report, 1869, p. 390	Spencer	9 a.m. preceding.	4 0	50
475.	Sept. 25.	NORFOLK. Outwell Sluice. *MID LEVEL COMMISSIONERS.* *Mr. W. Bond.*	VIII.	....	9 a.m. 6 p.m.	3 0	....
476.	Sept. 26.	CAMBRIDGE. Victoria Road, Wisbeach. *S. H. MILLER, ESQ.* *S. H. Miller, Esq.*	XI.	Negretti & Zambra	9 a.m.	0 6	10
477.	Sept. 26.	CAMBRIDGE. Victoria Road, Wisbeach. *S. H. MILLER, ESQ.* *S. H. Miller, Esq.*	X.	Negretti & Zambra	9 a.m. preceding.	0 6	10
478.	Sept. 26.	CAMBRIDGE. Victoria Road, Wisbeach. *S. H. MILLER, ESQ.* *S. H. Miller, Esq.*	X.	Negretti & Zambra	....	8 0	18
479.	Dec. 4.	OXFORDSHIRE. Banbury. *T. BEESLEY, ESQ.* *T. Beesley, Esq.*	VIII.	Anon...............	9 a.m. preceding.	7 0	350

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
7·94	·1	1270	−·001	W. House 20°.	Very open position, on almost the highest ground in the county.	469.
8·00	·2	2530	−·002			
7·93	·3	3750	−·001			
7·94	·4	5025	−·001			
M 7·953	·5	6290	−·001			
5·08	·1	498	−·001	N. Beech 40°. N.E. Church 25°.	On the east side of the rectory lawn, in a very good position.	470.
4·90	·2	990	correct.			
4·98	·3	1500	−·001			
5·01	·4	1980	correct.			
M 4·993	·5	2470	correct.			
4·98	·1	495	correct.	N.W. House 22°. N. Barn 18°.	In small paddock; flat country, and quite open.	471.
5·03	·2	990	+·001			
4·98	·3	1470	+·004			
5·03	·4	1980	+·001			
M 5·005	·5	2470	+·003			
7·98	·1	1280	−·001	S.W. Trees 35°. N.E. „ 30°.	In garden, near to, but not influenced by, house.	472.
8·02	·2	2550	−·001			
8·00	·3	3820	−·001			
8·00	·4	5090	−·001			
M 8·000	·5	6370	−·002			
5·00	·1	495	correct.	....	In same garden as No. 472, but much further from house, and quite open.	473.
5·00	·2	980	+·002			
5·00	·3	1490	correct.			
5·01	·4	1970	+·003			
M 5·003	·5	2470	+·002			
3·00	....	....	....	N.W. Pear 60°. S.E. Acacia 52°.	A very shaky gauge, mounted on a stone pillar, but so loosely fixed that it could be blown from side to side. The gauge itself is also very incorrect, and the position bad. As observations have been made for many years and with regularity this is to be regretted.	474.
3·00	·26	490	−·014			
3·00	·53	990	−·025			
3·02	·795	1480	−·032			
M 3·005	1·07	1990	−·041			
9·02	·05	810	correct.	....	A very good gauge in a good position, but most wofully out of order. It was in a wooden box with what had been a flat top, through which the funnel only rose half an inch; and even this was reduced by the warping of the split wood. It is impossible to form any opinion of the probable error due to this arrangement.	475.
8·98	·1	1630	−·002			
8·98	·15	2430	−·002			
8·96	·2	3200	correct.			
M 8·985	·25	4000	correct.			
4·99	·1	510	−·003	N. Trees 33°. N.W. „ 25°.	Nos. 476 and 477 were close together in a small garden much shut in by trees; the observer said that he had cut down several, and promised to make a further clearance.	476.
5·00	·2	1040	−·010			
4·99	·3	1530	−·011			
5·00	·4	2050	−·014			
M 4·995	·5	2530	−·011			
8·00	·1	1250	+·001	N. Trees 33°. N.W. „ 25°.		477.
7·98	·2	2480	+·004			
7·98	·3	3720	+·006			
8·00	·4	5040	+·002			
M 7·990	·5	6290	+·003			
7·98	·1	1250	+·001	....	On the roof of thermometer-stand, about 15 ft. from No. 477. Unsheltered.	478.
7·92	·2	2480	+·002			
7·94	·3	3720	+·004			
7·99	·4	5040	−·001			
M 7·958	·5	6290	−·001			
6·09	·1	700	+·004	S. Birch 30°. E. „ 32°. W. „ 42°. N. House 53°.	On roof of outhouse, in the best position on the premises.	479.
6·00	·2	1410	+·006			
6·12	·3	2170	+·001			
5·98	·4	2880	+·003			
M 6·048						

Seventh Report of the Committee appointed for the purpose of continuing Researches in Fossil Crustacea, consisting of Professor P. MARTIN DUNCAN *(M.B. Lond.), F.R.S.,* HENRY WOODWARD, *F.R.S., and* ROBERT ETHERIDGE, *F.R.S. Drawn up by* HENRY WOODWARD, *F.R.S.*

LAST year at the Brighton Meeting I was enabled to lay before the Association a very considerable list of accessions to Fossil Crustacea, and also a goodly account of work performed.

A very fruitful season is not unfrequently succeeded by a smaller harvest. Such is the case with my Report this year; I am, however, able to show some favourable results.

Part V. of my 'Monograph on the Merostomata,' containing the suborder XIPHOSURA, will be ready for publication before the end of the present year. I have included in it the following genera and species, namely:—

Bellinurus Konigianus,	H. Woodw., 1872.	Coal-measures,	Dudley.	
—— *bellulus.*	Konig.	„	Coalbrookdale.	
—— *reginæ,*	Baily.	„	Queen's Co., Ireland.	
—— *arcuatus,*	„	„	„	„
Prestwichia Birtwelli, sp. nov.,	H. Woodw.	„	Lancashire.	
—— *anthrax,*	„ 1866.	„	Coalbrookdale.	
—— *rotundata,*	„ „	„	„	
Neolimulus falcatus,	„ „	Upper Silurian,	Lanarkshire.	

I have also introduced into this Part of my Monograph those singular crustacean forms which occur in the Carboniferous Limestone, both at Cork in Ireland, at Settle and Bolland in Yorkshire, and at Visé, Belgium, referred to the genus *Cyclus,* namely:—

Cyclus bilobatus,	H. Woodw.	Carboniferous Limestone,	Ireland.
—— *torosus,*	„	„ „	„
—— *Wrightii,*	„	„ „	„
—— *Harknessi,*	„	„ „	„
—— *radialis,*	Phillips, sp.	„ „	Yorkshire, &c.
—— *Jonesianus,*	H. Woodw.	„ „	Ireland.
—— *Rankini,*	„	Coal-shale,	Carluke.
—— (*Halicyne*) *laxus,*	von Meyer.	Muschelkalk,	Germany.
—— (*Halicyne*) *agnostus,*	„	„	„

These last are doubtless either larval forms of other Crustacea, or else they belong to a peculiar group whose appearance in time has been exceedingly limited. They remain for the present among the unsolved problems of palæozoology.

Whilst referring to the fossil *Limuli* I would briefly allude to two valuable contributions to the anatomy of the living *Limulus,* or "King crab," of the north-east coast of North America:—one by my distinguished colleague and chief, Prof. Owen (see Linnean Transactions, 1873, vol. xxviii. pt. iii. p. 459, pls. xxxvi.–xxxix.); the other by Prof. Alphonse Milne-Edwards (in the 'Annales des Sciences Naturelles, Zoologie,' 5th series, tome xvii. 1873, p. 25, pls. v.–xvi.).

Limulus polyphemus, and the closely allied species common to the Moluccas and the coasts of China and Japan, are the sole existing types of this ancient race, whose longevity (as an order) in time is unsurpassed among the Crustacea, save by the Entomostraca alone, *Neolimulus* of the Upper Silurian of Lanark closely agreeing with the larval stages of the living *Limulus,* called by Dohrn the "Trilobiten-Stadium."

By the kindness of Professor Owen I am permitted to add three plates from his Memoir on the modern American King crab to illustrate my 'Monograph on Fossil *Limuli*.' I have also introduced (from Dr. Packard's and Dr. Dohrn's works) figures of the larval stages of *Limulus polyphemus*; and from that of Barrande figures of the larval forms of certain Trilobites, the development of which he has traced often (as in the case of *Sao hirsuta*) through more than twenty stages.

Having read carefully the arguments of Dr. Dohrn, and subsequently the views of Dr. Packard, the elaborate papers on the anatomy of *Limulus* by Alphonse Milne-Edwards and Prof. Owen, I find nothing in these several memoirs to lead me to distrust the conclusion at which I had arrived in 1866 (see Brit. Assoc. Reports, Nottingham, and Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 28) as to the correctness of associating the EURYPTERIDA and XIPHOSURA under the Order MEROSTOMATA, but much to confirm and strengthen that conclusion.

Prof. Owen fully concurs in my general views of the MEROSTOMATA, as an order, although he differs from me in some minor points in reference to the structure of *Limulus*.

For example, he considers the anterior shield, as I do, to be the cephalon, merely proposing for it the term *cephaletron** ; whilst for the posterior shield (which I demonstrated in 1866 to be the conjoined thorax and abdomen) he gives the name *thoracetron* ; and to the telson, or tail-spine, he applied Mr. Spence Bate's name of "*pleon*."

There can be no objection to the term "cephaletron," as proposed by Prof. Owen, for the head in Crustacea, in contradistinction to that highly specialized division of the body, the "head" in the *Vertebrata* ; but I think I have shown good grounds (in the paper above referred to) for assuming that the posterior shield is *not merely* the thorax (or "*thoracetron*" of Owen), but the combined thoracic and abdominal segments, as attested by the larval or embryonal stages of *Limulus*, and by the fossil forms of the Coal-measures and of the Silurian.

I venture also to demur to Spence Bate's term "pleon" being restricted to the tail-spine in *Limulus*, because it is calculated, if so used, to cause considerable confusion. The term "pleon," as applied to the Crustacea by its author, includes the last *seven segments* of the body, of which the *telson* (if reckoned at all as being a segment) can only be assumed to be the ultimate joint of the series.

The view propounded by Prof. Owen—that the great caudal spine in *Limulus* represents, either by itself or possibly with the hindmost segments of the "thoracetron" (Owen), the "pleon" of Spence Bate (or in other words the last seven (or abdominal) segments usually seen in other Crustacea)—is based on his examination of the innervation of the tail-spine. From its dissection he finds that the bifid continuation of the great neural axis is divided within the triangular tail-sheath into a double plexus of fine nerves resembling the *cauda equina* of anthropotomy. In this fasciculus of nerve-threads the author traces nine nerve-filaments, four ventral and four dorsal, the ninth being the continuation of the bifid neural axis. From this he concludes that the tail-spine may indicate as many as four coalesced segments, which with the three posterior coalesced apodal segments of the "thoracetron" would account for the missing abdominal series, or the "pleon" of Spence Bate.

* From κεφαλή, *the head*, and ἦτρον, *a part of the abdomen*, in allusion to the fact that "a part of such cavity is associated with the 'head' in the first division of the King crab's body, and with the 'thorax' in the second division." (Owen, *op. cit.* p. 463.)

But, notwithstanding my profound respect and appreciation of Professor Owen's comparative anatomical studies and his conclusions thereon, I find great difficulty in adopting this view, because it does not accord with those generally entertained regarding similar structures in other orders of Crustacea; neither will it harmonize with the earliest known forms of the XIPHOSURA, nor with the larval development of recent *Limulus* as made known by the researches of Packard* and Dohrn†.

Prof. Owen names the small modified bifid median appendage behind the mouth of *Limulus* the "chilaria"‡; this is doubtless the homologue of the great metastomial plate of *Pterygotus*§.

Dr. Packard, when contrasting (in his work on Larval *Limulus*, *op. cit.*) the MEROSTOMATA with the TRILOBITA, inadvertently calls the "Metastome" the "Hypostome," and contrasts it with the *Hypostome* in Trilobites, in which no lower lip exists.

Referring to the habits of the *Pterygoti*, Prof. Owen considers they were those of burrowers like the *Limuli*; but their bodies and broad swimming-feet seem preeminently fitted for natation.

On the other hand, he thinks *Limulus* could not walk well, but only crawl and burrow. I have frequently seen them alive in the Aquaria at the Zoological Gardens; and they walked with considerable ease and activity on the tips of their toes. They are, however, true burrowers by habit.

Prof. Owen is willing to accept the theory of development of the MEROSTOMATA from a typical and common life-form, but by "Secondary causes or laws," *not* by Natural selection (p. 501 *op. cit.*).

Several additions have been made to the Carboniferous Phyllopods, the species of which I have described in conjunction with my friend Mr. Robert Etheridge, jun. (of the Geological Survey of Scotland); some notice of these will be found in the Transactions of the Sections (C.), in a separate paper.

Of Cretaceous forms I have examined several new species, among which are three examples of the carapace of a small Gault Crustacean from Folkestone (near to *Diaulax Carteri*, from the Cambridge Greensand), which I have named *D. feliceps*, two small forms of *Scyllaridia*, the genus hitherto only known in the Eocene Tertiary:—

Scyllaridia Gardneri, sp. nov.
—— *punctata*, sp. nov.

A small *Crangon*? of doubtful determination, with two delicately serrated lines on the anterior half of the carapace in front of the nuchal furrow, and the hinder part armed with very minute spines, the surface of the carapace being ornamented with very minute and scattered serrations; the carapace, hands, and detached body-segments of which are all of a glistening black enamel. I have named this *Mesocrangon atra*‖.

Fifteen years ago Mr. Charles Gould, F.G.S., described¶ a very imperfectly

* "The Development of *Limulus polyphemus*," by A. S. Packard, Jun., M.D., Mem. Boston Soc. Nat. Hist., 1872, vol. xi. pp. 155–202, pls. iii.–v.

† "Zur Embryologie und Morphologie des *Limulus polyphemus*," von Dr. Anton Dohrn, Jenaische Zeitschrift, Band vi. Heft iv. p. 580, Taf. 14 und 15 (1871).

‡ From χειλάριον, *a small lip* (Owen, *op. cit.* p. 464).

§ As pointed out by me: see Brit. Association Reports, Edinburgh, August 1871, Fifth Report on Fossil Crustacea, p. 53.

‖ These specimens are from the collection of J. Starkie Gardner, Esq., F.G.S., who has kindly placed them at my disposal for examination with others.

¶ Quart. Journ. Geol. Soc. 1859, vol. xv. p. 237. See also Bell's Mon. Pal. Soc. Crustacea of the Gault and Greensand, 1862, p. 1, pl. i. figs. 2 and 3.

preserved carapace of a small crustacean under the name of *Mithracites vectensis*, from the Greensand, Atherfield, Isle of Wight. I lately obtained six specimens from the same locality, which upon comparison I found to agree (so far as the figures and description enabled me to determine) with Gould's *Mithracites*; but when I compared the specimens with the recent *Mithrax*, I failed to discover the analogy, although the specimens since obtained appear to offer a decided affinity with the genus *Hyas*. The discovery of these additional examples will necessitate the reconsideration and redescription of the genus *Mithracites*.

Fortunately the abdomen and limbs of both male and female examples are preserved; and the margins of the carapace are also well seen.

From the Greensand, Isle of Wight, I have also obtained a new species of *Hemioon*? (Bell), but larger than *H. Cunningtoni*. From the Hard Chalk, Dover, I have received a new form of *Enoploclytia*, which I propose to call *E. scabrosa*.

Only one new species of Trilobite has to be noticed; it was found at Utah, and sent over by Mr. Henry S. Poole, Inspector of Mines, Nova Scotia. I have referred it to the genus *Olenus*, under the name of *Olenus utahensis*. It shows evidence of a median axis, apparently corresponding with the so-called *straight alimentary canal*, noticed by Barrande. The matrix is composed of a hydrated silicate of magnesia.

This completes the list of new forms examined and determined by me, some of which are already engraved for publication.

Report on Recent Progress in Elliptic and Hyperelliptic Functions. *By* W. H. L. Russell, *F.R.S.*

Part II. *On the System of Hyperelliptic Differential Equations adopted by Jacobi, Gopel, and Rosenhain.*

In this part the solutions of the hyperelliptic differential equations of the first order, as given by Gopel and Rosenhain, will form the main subject which I desire to bring before my readers. They will ever possess great interest, although surpassed in generality by the later researches of Weierstrass, and the geometrical methods of Riemann. The researches of Gopel and Rosenhain were nearly contemporary; as, however, those of Rosenhain are somewhat more elaborated than those of Gopel, I shall commence with an account of them, as contained in the 'Mémoires de l'Institut, par Divers Savants,' tom. xi. p. 361. Rosenhain begins his investigations by giving formulæ for the multiplication of four functions θ appertaining to elliptic integrals, and uses these as a starting-point for the corresponding formulæ in hyperelliptic functions. He then expresses these new functions θ in terms of two new variables, and shows that from the equations thus obtained we can deduce the hyperelliptic differential equations.

Section 1.—We commence with Rosenhain's multiplication of four functions θ in the case of elliptic integrals. His notation is as follows (it will be observed that he uses the same notation we have been already familiar with in Schellbach, except that his exponentials involve real quantities):—

$$\theta(v,q)=\sum_{n\,-\infty}^{\infty}(-1)^n q^{n^2}\epsilon^{2nv}=1-q(\epsilon^{2v}+\epsilon^{-2v})+q^4(\epsilon^{4v}+\epsilon^{-4v})-\&c.,$$

$$\theta_1(v,q)=\sum_{n\,-\infty}^{\infty}(-1)^n q^{\frac{(2n+1)^2}{4}}\epsilon^{(2n+1)v}=q^{\frac{1}{4}}(\epsilon^{v}-\epsilon^{-v})-q^{\frac{9}{4}}(\epsilon^{3v}-\epsilon^{-3v})+\ldots,$$

$$\theta_2(v,q)=\sum_{n\,-\infty}^{\infty}q^{\frac{(2n+1)^2}{4}}\epsilon^{(2n+1)v}=q^{\frac{1}{4}}(\epsilon^{v}+\epsilon^{-v})+q^{\frac{9}{4}}(\epsilon^{3v}+\epsilon^{-3v})+q^{\frac{25}{4}}(\epsilon^{5v}+\epsilon^{-5v})+\ldots,$$

$$\theta_3(v,q)=\sum_{n\,-\infty}^{\infty}q^{n^2}\epsilon^{2nv}=1+q(\epsilon^{2v}+\epsilon^{-2v})+q^4(\epsilon^{4v}+\epsilon^{-4v})+\ldots;$$

these functions are singly periodic, and their ratios doubly periodic. We have already seen that this periodicity has been fully discussed by Schellbach.

Now let us assume four new variables connected with the original variables by means of the equations

$$\begin{aligned}
2v_1 &=v+v'+v''+v''', &\text{ or }\quad 2v &=v_1+v_1'+v_1''+v_1''',\\
2v_1' &=v+v'-v''-v''', &\text{ or }\quad 2v' &=v_1+v_1'-v_1''-v_1''',\\
2v_1'' &=v-v'+v''-v''', &\text{ or }\quad 2v'' &=v_1-v_1'+v_1''-v_1''',\\
2v_1''' &=v-v'-v''+v''', &\text{ or }\quad 2v''' &=v_1-v_1'-v_1''+v_1''',
\end{aligned}$$

whence

$$v^2+v'^2+v''^2+v'''^2=v_1^2+v_1'^2+v_1''^2+v_1'''^2.$$

Hence $\theta_3(v)\theta_3(v')\theta_3(v'')\theta_3(v''')=\epsilon^{-\frac{v^2+v'^2+v''^2+v'''^2}{\log_\epsilon q}}\sum\epsilon^{\frac{P}{\log_\epsilon q}}$,

where

$$P=(v+n\log_\epsilon q)+(v'+n'\log_\epsilon q)^2+(v''+n''\log_\epsilon q)^2+(v'''+n'''\log_\epsilon q)^2$$

will remain unchanged, if v_1, v'_1, v''_1, v'''_1 be substituted for v, v', v'', v''', provided that

$$\begin{aligned}
2n_1 &=n+n'+n''+n''', &\text{ or }\quad 2n &=n_1+n_1'+n_1''+n_1''',\\
2n_1' &=n+n'-n''-n''', &\text{ or }\quad 2n' &=n_1+n_1'-n_1''-n_1''',\\
2n_1'' &=n-n'+n''-n''', &\text{ or }\quad 2n'' &=n_1-n_1'+n_1''-n_1''',\\
2n_1''' &=n-n'-n''+n''', &\text{ or }\quad 2n''' &=n_1-n_1'-n_1''+n_1'''.
\end{aligned}$$

Now n, n', n'', n''' are all whole numbers from $+\infty$ to $-\infty$; but as these equations are written we should have n'_1, n''_1, n''_1, n'''_1 including forms $\pm r$ and $\pm(r+\frac{1}{2})$ when r is any integer.

This inconvenience is removed by assuming that $2n$, $2n'$, $2n''$, $2n'''$ must be subject to the same condition to which $2n_1$, $2n'_1$, $2n''_1$, $2n'''_1$ are subject, namely of being all at once odd, or all at once even. Rosenhain shows (p. 373) that this necessitates the introduction of functions θ_2, and that we have

$$\begin{aligned}
&\theta_3(v)\theta_3(v')\theta_3(v'')\theta_3(v''')+\theta_2(v)\theta_2(v')\theta_2(v'')\theta_2(v''')\\
&\quad=\theta_3(v_1)\theta_3(v'_1)\theta_3(v''_1)\theta_3(v'''_1)+\theta_2(v_1)\theta_2(v'_1)\theta_2(v''_1)\theta_2(v'''_1)\,. \quad .\quad .\quad .\quad (1)
\end{aligned}$$

In putting

$$v+\frac{i\pi}{2},\ v'+\frac{i\pi}{2},\ v''+\frac{i\pi}{2},\ v'''-\frac{i\pi}{2} \text{ for } v, v', v'', v''',$$

we have

$$\theta(v)\theta(v')\theta(v'')\theta(v''')-\theta_1(v)\theta_1(v')\theta_1(v'')\theta_1(v''')$$
$$=\theta(v_1)\theta(v_1')\theta(v_1'')\theta(v_1''')-\theta_1(v_1)\theta_1(v_1')\theta_1(v_1'')\theta_1(v_1''')\,; \quad . \quad . \quad . \quad (2)$$

and if we substitute $v'''+i\pi$ in the place of v''' in these two equations, we shall have:—

$$\theta_3(v)\theta_3(v')\theta_3(v'')\theta_3(v''')-\theta_2(v)\theta_2(v')\theta_2(v'')\theta_2(v''')$$
$$=\theta(v_1)\theta(v_1')\theta(v_1'')\theta(v_1''')+\theta_1(v_1)\theta_1(v_1')\theta_1(v_1'')\theta_1(v_1''')\,; \quad . \quad . \quad (3)$$
$$\theta(v)\theta(v')\theta(v'')\theta(v''')+\theta_1(v)\theta_1(v')\theta_1(v'')\theta_1(v''')$$
$$=\theta_3(v_1)\theta_3(v_1')\theta_3(v_1'')\theta_3(v_1''')-\theta_2(v_1)\theta_2(v_1')\theta_2(v_1'')\theta_2(v_1'''). \quad . \quad . \quad (4)$$

Section 2.—Putting, then, for a moment

$$\theta^{(r)}=\theta_r(v)\theta_r(v')\theta_r(v'')\theta_r(v'''),\quad \theta^{(r)}{}_1=\theta_r(v_1)\theta_r(v'_1)\theta_r(v''_1)\theta_r(v'''_1),$$

we have, adding (1) and (3), secondly subtracting (3) from (1), thirdly adding (2) and (4), fourthly subtracting (2) from (4),

$$2\theta^{(3)}=\theta_1{}^{(3)}+\theta_1{}^{(2)}+\theta_1+\theta_1{}^{(1)},$$
$$2\theta^{(2)}=\theta_1{}^{(3)}+\theta_1{}^{(2)}-\theta_1-\theta_1{}^{(1)},$$
$$2\theta\ \ =\theta_1{}^{(3)}-\theta_1{}^{(2)}+\theta_1-\theta_1{}^{(1)},$$
$$2\theta^{(1)}=\theta_1{}^{(3)}-\theta_1{}^{(2)}-\theta_1+\theta_1{}^{(1)};$$

from which

$$\theta^2+\theta^{(1)2}+\theta^{(2)2}+\theta^{(3)2}=\theta_1{}^2+\theta_1{}^{(1)2}+\theta_1{}^{(2)2}+\theta_1{}^{(3)2}, \text{ or}$$
$$\{\theta_3v\theta_3v'\theta_3v''\theta_3v'''\}^2+\{\theta_2v\theta_2v'\theta_2v''\theta_2v'''\}^2+\{\theta_1v\theta_1v'\theta_1v''\theta_1v'''\}^2+\{\theta v\theta v'\theta v''\theta v'''\}^2$$

remains unchanged when v_1, v'_1, v''_1, v'''_1 are put for v, v', v'', v'''.

This and four other formulæ of a similar nature, obtained by augmenting the arguments by semiperiods &c., are given by Rosenhain, and constitute the starting-point from which he deduces the properties of the hyperelliptic functions, as we shall soon see. See also a memoir by Professor Smith on this subject in the 'Transactions' of the London Mathematical Society.

Section 3.—Conceive now a function thus defined:

$$\phi_{3,3}(v, w)=\sum_{m=-\infty}^{\infty} p^{m^2}\epsilon^{2mv}\theta_3(w+2m\mathrm{A}, q),$$
$$=\sum_{n=-\infty}^{\infty} q^{n^2}\epsilon^{2nw}\theta_3(v+2n\mathrm{A}, p),$$
$$=\sum_{m=-\infty}^{\infty}\sum_{n=-\infty}^{\infty}\epsilon^{m^2\log_\epsilon p+n^2\log_\epsilon q+4mn\mathrm{A}+2mv+2nw}.$$

This series is a function, doubly periodic (see Rosenhain, p. 389), of v and w in the pairs of conjugate indices $i\pi$ and 0 and 0 and $i\pi$; for we have

$$\phi_{3,3}(v+ai\pi, w)=\phi_{3,3}(v, w),$$

$$\phi_{3,3}(v, w+ai\pi)=\phi_{3,3}(v, w),$$

a being a whole number.

We see at once that (β and γ being any whole numbers)

$$\phi_{3,3}\{v+\beta\log_\epsilon p+2\gamma A,\quad w+2\beta A+\gamma\log_\epsilon q\}=\epsilon^{-M}\phi_{3,3}(v, w),$$

where we have for M

$$M=\beta^2\log_\epsilon p+\gamma^2\log_\epsilon q+4\beta\gamma A+2\beta v+2\gamma w_1{}^*.$$

Now, then, consider the quantity

$$\epsilon^{\frac{v^2\log_\epsilon q+w^2\log_\epsilon p-4Avw}{\log_\epsilon p\log_\epsilon q-4A^2}}\phi_{3,3}(v, w):$$

and substitute in this formula $v+\beta\log_\epsilon p+2\gamma A$ for v, and $w+\gamma\log_\epsilon q+2\beta A$ for w, and the formula becomes

$$\epsilon^{\frac{v^2\log_\epsilon q+w^2\log_\epsilon p-4Avw}{\log_\epsilon p\log_\epsilon q-4A^2}+M}\phi_{3,3}(v+\beta\log_\epsilon p+2\gamma A, w+\gamma\log_\epsilon q+2\beta A),$$

or

$$\epsilon^{\frac{v^2\log_\epsilon p+w^2\log_\epsilon p-4Avw}{\log_\epsilon p\log_\epsilon q-4A^2}}\phi_{3,3}(v, w),$$

and therefore remains unchanged. We shall soon meet with a series of functions similar to $\phi_{3,3}(v, w)$ and doubly periodic; this theorem will enable us to show that the ratios of these functions are also doubly periodic with different periods (p. 411).

Let
$$V=\frac{v\log_\epsilon q-2Aw}{\log_\epsilon p\log_\epsilon q-4A^2}\,.\;W=\frac{w\log_\epsilon p-2Av}{\log_\epsilon p\log_\epsilon q-4A^2},$$

then

$$\epsilon^{\frac{v^2}{\log_\epsilon p}+\frac{\log_\epsilon p\log_\epsilon q-4A^2}{\log_\epsilon p}W^2}\cdot\phi_{3,3}(v, w)=\Sigma_n{}_{-\infty}^{\infty}\epsilon^{\frac{\log_\epsilon p\log_\epsilon q-4A^2}{\log_\epsilon p}(W+n)^2}$$

$$\epsilon^{\frac{(v+2nA)^2}{\log_\epsilon p}}\theta_3(v+2An, p), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\epsilon^{\frac{w^2}{\log_\epsilon q}+\frac{\log_\epsilon p\log_\epsilon q-4A^2}{\log_\epsilon q}V^2}\phi_{3,3}(v, w)=\Sigma_m{}_{-\infty}^{\infty}\epsilon^{\frac{\log_\epsilon p\log_\epsilon q-4A^2}{\log_\epsilon p}(V+m)^2}$$

$$\cdot\,\epsilon^{\frac{(w+2mA)^2}{\log_\epsilon q}}\theta_3(w+2Am, q), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

To prove this, write down the fully expanded form of

$$\epsilon^M\phi_{3,3}(v+\beta\log_2 p+2\gamma A, w+2\beta A+\gamma\log_\epsilon q).$$

From the formula

$$\frac{\theta(iu+\mathrm{K},k)}{\theta(0,k)}=\frac{\sqrt{k}}{\sqrt{k'}}\epsilon^{\frac{\pi u^2}{4\mathrm{KK}'}}\cdot\frac{\theta(u+\mathrm{K}',k')}{\theta(0,k')},$$

given by Jacobi in the 'Fundamenta Nova,' p. 165, Rosenhain deduces the following (p. 395):—

$$\epsilon^{\frac{v^2}{\log_\epsilon p}}\theta_3(v,p)=\sqrt{-\frac{\pi}{\log_\epsilon p}}\,\theta_3(iv',p'),$$

where

$$\log_\epsilon p=-\frac{\pi\mathrm{K}'}{\mathrm{K}},\quad \log_\epsilon p'=-\frac{\pi\mathrm{K}}{\mathrm{K}'},\quad v'=\frac{\pi v}{\log_\epsilon \pi}.$$

He then enunciates the following theorem:—

$$\epsilon^{\frac{v^2}{\log_\epsilon p}}\phi_{3,3}(v,w,p,q,\mathrm{A})=\sqrt{-\frac{\pi}{\log_\epsilon p}}\,\phi_{3,3}(iv',w',p',q',\mathrm{A}')$$

where

$$\log_\epsilon p\log_\epsilon p'=\pi^2=\frac{\log_\epsilon p\log_\epsilon q-4\mathrm{A}^2}{\log_\epsilon q}\cdot\frac{\log_\epsilon p'\log_\epsilon q'-4\mathrm{A}'^2}{\log_\epsilon q'},$$

$$\log_\epsilon q'=\frac{\log_\epsilon p\log_\epsilon q-4\mathrm{A}^2}{\log_\epsilon p},\quad \log_\epsilon q=\frac{\log_\epsilon p'\log_\epsilon q'-4\mathrm{A}'^2}{\log_\epsilon p'},$$

$$\mathrm{A}'=\frac{i\pi\mathrm{A}}{\log_\epsilon p},\quad i\mathrm{A}=\frac{\pi\mathrm{A}'}{\log_\epsilon p'},$$

$$v'=\frac{\pi v}{\log_\epsilon p},\quad w'=\frac{w\log_\epsilon p-2\mathrm{A}v}{\log_\epsilon p},$$

$$v=\frac{\pi v'}{\log_\epsilon p'},\quad w=\frac{w'\log_\epsilon p'-2i\mathrm{A}'v'}{\log_\epsilon p'}.$$

To prove this theorem, which is enunciated without demonstration, I observe that

$$v+2n\mathrm{A}=\frac{\pi}{\log_\epsilon p}(v'-2ni\mathrm{A}'),$$

according to supposition.

Wherefore by formula (1) of this section

$$\epsilon^{\frac{v^2}{\log_\epsilon p}+\frac{\log_\epsilon p\log_\epsilon q-4\mathrm{A}^2}{\log_\epsilon p}\mathrm{W}^2}\phi_{3,3}(v,w)=$$

$$\sum_{-\infty}^{\infty}{}_n\,\epsilon^{\frac{\log_\epsilon p\log_\epsilon q-4\mathrm{A}^2}{\log_\epsilon p}(\mathrm{W}+n)^2}\cdot\sqrt{-\frac{\pi}{\log_\epsilon p}}\,\theta_3(iv'+2n\mathrm{A}',p')$$

(by the formula just derived from the 'Fundamenta Nova').

Consequently

$$\epsilon^{\frac{v^2}{\log_\epsilon p}} \phi_{3,3}(v, w, p, q, A)$$

$$= \sum_{-\infty}^{\infty}{}_n \epsilon^{\frac{\log_\epsilon p \log_\epsilon q - 4A^2}{\log_\epsilon p}(2nW + n^2)} \cdot \sqrt{-\frac{\pi}{\log_\epsilon p}} \sum_{-\infty}^{\infty}{}_m p'^{m^2} \epsilon^{2m(iv' + 2nA')}.$$

But

$$W = \frac{w \log_\epsilon p - 2Av}{\log_\epsilon p \log_\epsilon q - 4A^2} = \frac{w' \log_\epsilon p}{\log_\epsilon p \log_\epsilon q - 4A^2}.$$

Hence

$$\epsilon^{\frac{v^2}{\log_\epsilon p}} \phi_{3,3}(v, w, p, q, A)$$

$$= \sqrt{-\frac{\pi}{\log_\epsilon p}} \sum_{-\infty}^{\infty}{}_n \epsilon^{2nw' + n^2 \log_\epsilon q'} \sum_{-\infty}^{\infty}{}_m \epsilon^{m^2 \log_\epsilon p'} \cdot \epsilon^{2miv' + 4nmA'}$$

$$= \sqrt{-\frac{\pi}{\log_\epsilon p}} \Sigma\Sigma \epsilon^{n^2 \log_\epsilon q' + 4nmA' + m^2 \log_\epsilon p' + 2miv' + 2nw'}$$

$$= \sqrt{-\frac{\pi}{\log_\epsilon p}} \phi_{3,3}(iv', w', p', q', A').$$

Rosenhain gives two other theorems of a precisely analogous nature (p. 397) for transforming

$$\epsilon^{\frac{v^2}{\log_\epsilon q}} \phi_{3,3}(v, w, p, q, A) \text{ into } \phi_{3,3}(v_1, iw_1, p_1, q_1, A_1),$$

and also

$$\epsilon^{\frac{v^2 \log_\epsilon q + w^2 \log_\epsilon p - 4Avw}{\log_\epsilon p \log_\epsilon q - 4A^2}} \phi_{3,3}(v, w, p, q, A) \text{ into } \phi_{3,3}(iv'_1, iw'_1, p'_1, q'_1, A'_1),$$

where the new variables and constants emanate from the former according to a certain law.

Section 4.—Rosenhain next enters upon investigations relative to the multiplication of functions θ, commencing with elliptic functions, and thence advancing to hyperelliptic functions. He proves without difficulty that, by directly multiplying the functions θ_3 together,

$$\prod_1^n{}_h \theta_3(w + \alpha_h, q) = \sum_0^{n-1}{}_a P_a \epsilon^{2aw} \theta_3(nw + s + a \log_\epsilon q, q^n), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$nP_a \epsilon^{2aw} \theta_3(nw + s + a \log_\epsilon q, q^n) = \sum_0^{n-1}{}_k \epsilon^{-\frac{2kai\pi}{n}} \prod_1^n{}_h \theta_3\left(w + \alpha_h + \frac{ki\pi}{n}, q\right), \quad . \quad . \quad (2)$$

and P_a is a certain constant,—where, as is obvious, the product Π extends to the quantities $\alpha_1, \alpha_2 \ldots \alpha_n$, $s = \alpha_1 + \alpha_2 + \alpha_3 + \ldots + \alpha_n$, and a is an integer less than (n).

To reduce this he makes use of the following theorem :—

$$nq^{a^2}\epsilon^{2aw}\theta_3(nw+an\log_\epsilon q, q^{n^2})=\sum_0^{n-1}{}_k\epsilon^{-\frac{2aki\pi}{n}}\theta_3\left(w+\frac{ki\pi}{n}, q\right) \quad . \quad . \quad . \quad . \quad (3)$$

As Rosenhain has not demonstrated this formula, I give the proof here. Let

$$\phi\left(\frac{ki\pi}{n}\right)=\chi(0)+\chi(1)\epsilon^{\frac{2ki\pi}{n}}+\chi(2)\epsilon^{\frac{4ki\pi}{n}}+\ldots.+\chi(n-1)\epsilon^{\frac{2(n-1)ki\pi}{n}}.$$

In $\frac{rm}{s}$, where (s) is a prime number, all the remainders are different as m increases from 0 to $s-1$. Hence we easily see, forming n linear equations, by putting $k=0, 1 \ldots . n-1$,

$$n\chi(r)=\Sigma_k\epsilon^{-\frac{2rki\pi}{n}}\phi\left(\frac{ki\pi}{n}\right).$$

But

$$\theta_3\left(w+\frac{ri\pi}{n}, q\right)=\sum_{-\infty}^{\infty}{}_m q^{m^2}\epsilon^{2m\left(w+\frac{ri\pi}{n}\right)},$$

$$\sum_0^{n-1}{}_r\epsilon^{-\frac{2ari\pi}{n}}\theta_3\left(w+\frac{ri\pi}{n}, q\right)=\sum_{-\infty}^{\infty}{}_m\sum_0^{n-1}{}_r q^{m^2}\epsilon^{2mw\frac{2(m-a)ri\pi}{n}}$$

$$=\sum_{-\infty}^{\infty}{}_m\sum_0^{n-1}{}_r q^{(m+a)^2}\epsilon^{2(m+a)w}\epsilon^{\frac{2mri\pi}{n}}=\sum_{-\infty}^{\infty}{}_m q^{(m+a)^2}\epsilon^{2(m+a)w}\cdot\frac{1-\epsilon^{2mi\pi}}{1-\epsilon^{\frac{2mi\pi}{n}}}.$$

This expression vanishes except when $m=n\mu$, μ being an integer, or

$$\sum_0^{n-1}{}_r\epsilon^{-\frac{2ari\pi}{n}}\theta_3\left(w+\frac{ri\pi}{n}, q\right)=nq^{a^2}\epsilon^{2aw}\sum_{-\infty}^{\infty}{}_\mu q^{\mu^2n^2}\epsilon^{2n\mu w+2n\mu a\log_\epsilon q}$$

$$=nq^{a^2}\epsilon^{2aw}\theta_3(na\log_\epsilon q+nw, q^{n^2}),$$

the formula required.

This formula may be written

$$nq^{\frac{a^2}{n}}\epsilon^{2aw}\theta_3(nw+a\log_\epsilon q, q^n)=\sum_0^{n-1}{}_r\epsilon^{-\frac{2ari\pi}{n}}\theta_3\left\{w+\frac{ri\pi}{n}, q^{\frac{1}{n}}\right\},$$

so that equation (1) becomes

$$n\Pi_1^n{}_h\theta_3(w+a_h, q)=\sum_0^{n-1}{}_r Q_r\theta_3\left(w+\frac{s}{n}+\frac{ri\pi}{n}, q^{\frac{1}{n}}\right).$$

Rosenhain then shows how, by giving w the n values

$$w, w+\frac{1}{n}\log_\epsilon q, \quad w+\frac{2}{n}\log_\epsilon q, \ldots . w+\frac{n-1}{n}\log_\epsilon q,$$

we may obtain n equations to determine the constants Q_r in terms of functions θ with constant arguments.

Section 5.—These principles are then applied to the multiplication of hyperelliptic functions. The following theorem is given without demonstration, $\phi_{3,3}(v, w)$ being the same as before:

$$\prod_{1}^{n}{}_h\phi_{3,3}(v+a_h, w+b_h, p, q, A)=$$

$$\sum_{0}^{n-1}{}_\beta\sum_{0}^{n-1}{}_\gamma A_{\beta,\gamma}\epsilon^{2\beta v+2\gamma w}\phi_{3,3}(nv+\Sigma a_h+\beta\log_\epsilon p+2\gamma A, nw+\Sigma b_h+2\beta A+\gamma\log_\epsilon q, p^n, q^n A)$$

where $A_{\beta,\gamma}$ is a constant analogous to Q_r in the last section.

To prove this formula we proceed as follows: the notation and assumptions will be understood by referring to Rosenhain, p. 400. To prevent confusion, we write ρ for Rosenhain's n.

$$\prod_{1}^{\rho}{}_h\phi_{3,3}(v+a_\rho, w+b_h)=\Sigma\Sigma$$

$$\epsilon^{(m_1^2+m_2^2+m_3^2+\ldots\ldots+m_\rho^2)\log_\epsilon p+(n_1^2+n_2^2+\ldots\ldots n_\rho^2)\log_\epsilon q}.$$

$$\epsilon^{4(m_1n_1+m_2n_2+m_3n_3+\ldots\ldots m_\rho n_\rho)A}.$$

$$\epsilon^{2(m_1+m_2+m_3+\ldots\ldots m_\rho)v+2(n_1+n_2+n_3+\quad n_\rho)w}.$$

$$\epsilon^{2(m_1a_1+m_2a_2+\ldots\ldots m_\rho a_\rho)+2(n_1b_1+n_2b_2+\quad +n_\rho b_\rho)}.$$

Let

$$m_h=\mu_h+x, \text{ and also } \mu_1+\mu_2+\mu_3+\ldots\ldots+\mu_\rho=\beta,$$

so that

$$m_1+m_2+\ldots\ldots+m_\rho=\beta+\rho x,$$

$$n_h=\nu_h+y, \text{ and also } \nu_1+\nu_2+\ldots\ldots+\nu_\rho=\gamma,$$

so that

$$n_1+n_2+\ldots\ldots+n_\rho=\gamma+ny.$$

Then

$$m_1^2+m_2^2+\ \ldots\ +m_\rho^2=\Sigma\mu_h^2+2\beta x+\rho x^2,$$

$$n_1^2+n_2^2+\ldots\ldots n_\rho^2=\Sigma\nu_h^2+2\gamma y+\rho y^2,$$

$$m_1n_1+m_2n_2+\ldots\ldots+m_\rho n_\rho=\Sigma\mu_1\nu_1+\beta y+\gamma x+\rho xy.$$

Hence, collecting these results, and resuming the (n)

$$\prod_{1}^{n}\phi_{3,3}(v+a_h, w+b_h)$$

$$=\Sigma\Sigma A_{\beta,\gamma}\epsilon^{2\beta v+2\gamma w}\cdot\epsilon^{x^2.n\log_\epsilon p+4Anxy+y^2.n\log_\epsilon q}$$

$$\epsilon^{2x(\beta\log_\epsilon p+2\gamma A+\Sigma a_h+nv)}\epsilon^{2y(2\beta A+\beta\log_\epsilon q+\Sigma b_h+nw)}$$

$$=\Sigma A_{\beta,\gamma}\epsilon^{2\beta v+2\gamma w}\cdot\phi_{3,3}(nv+\beta\log_\epsilon p+2\gamma A+\Sigma a_h, nw+2\beta A+\beta\log_\epsilon q+\Sigma b_h, p^n, q^n, An), \quad (1$$

where $A_{\beta,\gamma}$ is a constant to be determined (see p. 404).

Now from the definition of $\phi_{3,3}(v, w)$ it is easy to see that

$$\sum_{0}^{n-1}{}_k \sum_{0}^{n-1}{}_l \epsilon^{-\frac{k\beta+l\gamma}{n}2i\pi}\phi_{3,3}\left(v+\frac{ki\pi}{n},\ w+\frac{li\pi}{n},\ p, q, \mathrm{A}\right)$$

$$=\Sigma\Sigma \sum_{-\infty}^{\infty}{}_x \sum_{-\infty}^{\infty}{}_y \epsilon^{x^2\log_\epsilon p+4xy\,.\,\mathrm{A}+y^2\log_\epsilon q+2xv+2yw}\epsilon^{\frac{2k(x-\beta)i\pi}{n}}\epsilon^{\frac{2l(y-\gamma)i\pi}{n}}$$

$$=\sum_{0}^{n-1}{}_k \sum_{0}^{l-1}{}_l \sum_{-\infty}^{\infty}{}_x \sum_{-\infty}^{\infty}{}_y \epsilon^{(x+\beta)^2\log_\epsilon p+4(x+\beta)(y+\gamma)\,.\,\mathrm{A}+(v+\gamma)^2\log_\epsilon q}$$

$$\epsilon^{2(x+\beta)v+2(y+\gamma)w}\,.\,\epsilon^{\frac{2kxi\pi}{n}}\epsilon^{\frac{2lyi\pi}{n}}$$

=(using the reasoning of section 4, and so putting nx for x, ny for y)

$$\Sigma n^2\,.\,p^{\beta^2}\epsilon^{2\beta(v+2\gamma\mathrm{A})}q^{\gamma^2}\epsilon^{2\gamma(w+2\beta\mathrm{A})}\sum_{-\infty}^{\infty}{}_x \sum_{-\infty}^{\infty}{}_y$$

$$\epsilon^{n^2x^2\log_\epsilon p+4n^2xy\mathrm{A}+n^2y^2\log_\epsilon q+2nx(\beta\log_\epsilon p+2\gamma\mathrm{A}+v)+2ny(\gamma\log_\epsilon q+2\beta\mathrm{A}+w)}$$

$$=n^2p^{\beta^2}\epsilon^{2\beta(v+\delta\gamma\mathrm{A})}q^{\gamma^2}\epsilon^{2\gamma(w+\delta\beta\mathrm{A})},$$

$$\phi_{3,3}(n(v+\beta\log_\epsilon p+2\gamma\mathrm{A}),\ n(w+\gamma\log_\epsilon q+2\beta\mathrm{A}),\ p^{n^2},\ q^{n^2},\ \mathrm{A}n^2),$$

whence

$$\sum_{0}^{n-1}{}_k \sum_{0}^{n-1}{}_l \epsilon^{-\frac{k\beta+l\gamma}{n}2i\pi}\phi_{3,3}\left(v+\frac{ki\pi}{n},\ w+\frac{li\pi}{n},\ p^{\frac{1}{n}},\ q^{\frac{1}{n}},\ \frac{\mathrm{A}}{n}\right)$$

$$=\mathrm{B}\epsilon^{2\beta v+2\gamma w}\,.\,\phi_{3,3}(nv+\beta\log_\epsilon p+2\gamma\mathrm{A},\ nw+\gamma\log_\epsilon q+2\beta\mathrm{A},\ p^n,\ q^n,\ \mathrm{A}n),\ . \quad (2)$$

which agrees with Rosenhain, p. 404.

Hence, combining (1) and (2) together, we obtain

$$\prod_{1}^{n}{}_h\phi_{3,3}(v+a_h,\ w+b_h,\ p,\ q,\ \mathrm{A})$$

$$=\sum_{0}^{n-1}{}_k \sum_{0}^{n-1}{}_l \mathrm{B}_{k,l}\phi_{3,3}\left(v+\frac{\Sigma a_h}{n}+\frac{ki\pi}{n},\ w+\frac{\Sigma b_h}{n}+\frac{li\pi}{n},\ p^{\frac{1}{n}},\ q^{\frac{1}{n}},\ \frac{\mathrm{A}}{n}\right)$$

(Rosenhain, p. 405).

In this way formulæ are found for the multiplication of hyperelliptic functions. Two others of a similar nature are given by Rosenhain, together with the expression just written down; and they are presented in a somewhat modified form on page 406. The quantities $\mathrm{B}_{k,l}$ are expressed by means of functions $\phi_{3,3}$ with constant arguments, by a method analogous to that by which the constants Q_r were determined previously.

Section 6.—Having thus discussed some of the properties of $\phi_{3,3}(v, w)$, Rosenhain proceeds to develop a number of similar functions defined as follows, p. 499:—

$$\phi_{3,r}(v, w)=\sum_{-\infty}^{\infty}{}_m p^{m^2}\epsilon^{2mv}\theta_r(w+2m\mathrm{A},\ q),$$

$$\phi_{r,3}(v, w)=\sum_{-\infty}^{\infty}{}_n q^{n^2}\epsilon^{2mw}\theta_r(v+2n\mathrm{A}, p),$$

$$\phi_{0,r}(v, w)=\sum_{-\infty}^{\infty}{}_m(-1)^m p^{m^2}\epsilon^{2mv}\theta_r(w+2m\mathrm{A}, q),$$

$$\phi_{r,0}(v, w)=\sum_{-\infty}^{\infty}{}_n(-1)^n q^{n^2}\epsilon^{2nw}\theta_r(v+2n\mathrm{A}, p),$$

$$\phi_{2,r}(v, w)=\sum_{-\infty}^{\infty}{}_m p^{\frac{(2m+1)^2}{4}}\epsilon^{(2m+1)v}\theta_r(w+(2m+1)\mathrm{A}, q),$$

$$\phi_{r,2}(v, w)=\sum_{-\infty}^{\infty}{}_n q^{\frac{(2n+1)^2}{4}}\epsilon^{(2n+1)w}\theta_r(v+(2n+1)\mathrm{A}, p),$$

$$\phi_{1,r}(v, w)=\Sigma(-1)^m p^{\frac{(2m+1)^2}{4}}\epsilon^{(2m+1)v}\theta_r(w+(2m+1)\mathrm{A}, q),$$

$$\phi_{r,1}(v, w)=\Sigma(-1)^n q^{\frac{(2n+1)^2}{4}}\epsilon^{(2n+1)w}\theta_r(v+(2n+1)\mathrm{A}, p),$$

where r denotes one of the indices 0, 1, 2, 3. It is manifest from this that there are sixteen of these functions, which may all be expressed under the form

$$\phi_{r,s}(v, w, p, q, \mathrm{A})=\Sigma\Sigma\epsilon^{m^2\log_\epsilon p+n^2\log_\epsilon q+4mn\mathrm{A}+2ma_{r,s}+2nb_{r,s}+c_{r,s}},$$

where $a_{r,s}$, $b_{r,s}$, $c_{r,s}$ are linear functions of v and w.

The periodicity of these functions is given by Rosenhain, pages 409, 410; and he then proceeds to develop the following theorem:—If

$$\begin{aligned}
2v_1 &= v+v'+v''+v''', & 2w_1 &= w+w'+w''+w''',\\
2v_1' &= v+v'-v''-v''', & 2w_1' &= w+w'-w''-w''',\\
2v_1'' &= v-v'+v''-v''', & 2w_1'' &= w-w'+w''-w''',\\
2v_1''' &= v-v'-v''+v''', & 2w_1''' &= w-w'-w''+w''',
\end{aligned}$$

also if

$$\begin{aligned}
\mathrm{M} &= \phi_{3,3}(v, w)\,\phi_{3,3}(v', w')\,\phi_{3,3}(v'', w'')\,\phi_{3,3}(v''', w''')\\
&\quad+\phi_{3,2}(v, w)\,\phi_{3,2}(v', w')\,\phi_{3,2}(v'', w'')\,\phi_{3,2}(v''', w'''),\\
\mathrm{M}' &= \phi_{2,3}(v, w)\,\phi_{2,3}(v', w')\,\phi_{2,3}(v'', w'')\,\phi_{2,3}(v''', w''')\\
&\quad+\phi_{2,2}(v, w)\,\phi_{2,2}(v', w')\,\phi_{2,2}(v'', w'')\,\phi_{2,2}(v''', w'''),\\
\mathrm{M}'' &= \phi_{1,3}(v, w)\,\phi_{1,3}(v', w')\,\phi_{1,3}(v'', w'')\,\phi_{1,3}(v''', w''')\\
&\quad+\phi_{1,2}(v, w)\,\phi_{1,2}(v', w')\,\phi_{1,2}(v'', w'')\,\phi_{1,2}(v''', w'''),\\
\mathrm{M}''' &= \phi_{0,3}(v, w)\,\phi_{0,3}(v', w')\,\phi_{0,3}(v'', w'')\,\phi_{0,3}(v''', w''')\\
&\quad+\phi_{0,2}(v, w)\,\phi_{0,2}(v', w')\,\phi_{0,2}(v'', w'')\,\phi_{0,2}(v''', w'''),
\end{aligned}$$

and also if M_1, M_1', M_1'', M_1''' are what M, M', M'', M''' become when v, v' and w, w' are substituted for v, v' and w, w', then

$$M+M'=M_1+M_1', \quad \ldots \quad (1)$$

$$M''-M'''=M_1''-M_1''', \quad \ldots \quad (2)$$

$$M-M'=M_1''+M_1''', \quad \ldots \quad (3)$$

$$M''+M'''=M_1-M_1'. \quad \ldots \quad (4)$$

It is a good way to prove form (1) by writing down the fully expanded forms of $\phi_{3,3}$, $\phi_{3,2}$ and then applying the principles of Section 1. Then Rosenhain has shown how to deduce (2), (3), (4) by merely changing the periods.

Section 7.—By increasing the arguments by semiperiods Rosenhain has deduced an immense number of formulæ, which he has placed in a table at the end of his memoir. We shall endeavour, first, to explain how this table is formed, and, secondly, how to use it. We remark especially that if v, v', v'', v''' are each augmented by $\frac{i\pi}{2}$, then v_1 is augmented by $i\pi$, and v_1', v_1'', v_1''' remain unchanged; but, on the other hand, if v, v', v'' are augmented by $\frac{i\pi}{2}$, and v''' diminished by $\frac{i\pi}{2}$, then v_1, v_1', v_1'' are also increased each by $\frac{i\pi}{2}$ and v_1''' diminished by $\frac{i\pi}{2}$. Again, if while v, v' remain the same v'' is increased and v''' diminished by $\frac{i\pi}{2}$, then v_1, v_1' also remain the same, and v_1'' is increased, v_1''' diminished by $\frac{i\pi}{2}$. So that the four equations of section 6 remain true when the variables are thus changed and the functions M transformed. Now, then, we will consider the Table. Formula 1*a* consists of the values of M, M', M'', M''' written down as given in section 6. Formula 1*d* is obtained by augmenting w, w', w'' by $\frac{i\pi}{2}$ and diminishing w''' by $\frac{i\pi}{2}$, formula 2*a* from 1*a* by augmenting v'' by $\frac{i\pi}{2}$ and diminishing v''' by $\frac{i\pi}{2}$ in 1*a*, formula 2*d* from 1*d* by augmenting v'' by $\frac{i\pi}{2}$ and diminishing v''' by $\frac{i\pi}{2}$. We need make no special remarks respecting 3*a*, 3*d*, 4*a*, 4*d*, which are proved in a similar manner. But when we come to 5*a* we meet with a change. The formulæ of page 410 (numbered 80), are then called in, and the arguments augmented by the quantities which render the ratios of the functions ϕ doubly periodic, and which we have discussed at full in the third section in reference to $\phi_{3,3}(v, w)$. We thus obtain 5*a*, and from this, by changing the arguments as before by adding and subtracting $\frac{i\pi}{2}$, we arrive at 5*d*, 6*a*, 6*d*.

Now consider 6*d* particularly. It gives us

$$M-M'=M_1''+M_1''',$$

where

$$
\begin{aligned}
\mathrm{M} \ &=\phi_{2,0}(v,w)\,\phi_{2,0}(v',w')\,\phi_{0,0}(v'',w'')\,\phi_{0,0}(v''',w''') \\
&\quad -\phi_{2,1}(v,w)\,\phi_{2,1}(v',w')\,\phi_{0,1}(v'',w'')\,\phi_{0,1}(v''',w'''), \\
\mathrm{M}' \ &=\phi_{3,0}(v,w)\,\phi_{3,0}(v',w')\,\phi_{1,0}(v'',w'')\,\phi_{1,0}(v''',w''') \\
&\quad -\phi_{3,1}(v,w)\,\phi_{3,1}(v',w')\,\phi_{1,1}(v'',w'')\,\phi_{1,1}(v''',w'''), \\
\mathrm{M}_1'' &=\phi_{0,0}(v_1,w_1)\,\phi_{0,0}(v_1',w_1')\,\phi_{2,0}(v_1'',w_1'')\,\phi_{2,0}(v_1''',w_1''') \\
&\quad -\phi_{0,1}(v_1,w_1)\,\phi_{0,1}(v_1',w_1')\,\phi_{2,1}(v_1'',w_1'')\,\phi_{2,1}(v_1''',w_1'''), \\
\mathrm{M}_1''' &=\phi_{1,0}(v_1,w_1)\,\phi_{1,0}(v_1',w_1')\,\phi_{3,0}(v_1'',w_1'')\,\phi_{3,0}(v_1''',w_1''') \\
&\quad -\phi_{1,1}(v_1,w_1)\,\phi_{1,1}(v_1',w_1')\,\phi_{3,1}(v_1'',w_1'')\,\phi_{3,1}(v_1''',w_1''').
\end{aligned}
$$

Now let

$$v=v'=0,\quad w=w'=0,\qquad v''=-v''',\quad w''=-w''',$$

then

$$\phi_{2,1}=0,\quad \phi_{3,1}=0,\quad \phi_{0,1}=0,\quad \phi_{1,0}=0,$$

and the equation becomes, suppressing the accents,

$$\phi^2_{2,0}\,\phi^2_{0,0}(v,w)+\phi^2_{3,0}\,\phi^2_{1,0}(v,w)=\phi^2_{0,0}\,\phi^2_{2,0}(v,w)+\phi^2_{1,1}\,\phi^2_{3,1}(v,w)^*,$$

whence

$$
\left.
\begin{aligned}
1&=-\frac{\phi^2_{3,0}\,\phi^2_{1,0}(v,w)}{\phi^2_{2,0}\,\phi^2_{0,0}(v,w)}+\frac{\phi^2_{0,0}\,\phi^2_{2,0}(v,w)}{\phi^2_{2,0}\,\phi^2_{0,0}(v,w)}+\frac{\phi^2_{1,1}\,\phi^2_{3,1}(v,w)}{\phi^2_{2,0}\,\phi^2_{0,0}(v,w)}; \\
&\text{and similarly from } 8d \text{ and } 12d, \\
1&=-\frac{\phi^2_{3,3}\,\phi^2_{1,0}(v,w)}{\phi^2_{2,3}\,\phi^2_{0,0}(v,w)}+\frac{\phi^2_{0,3}\,\phi^2_{2,0}(v,w)}{\phi^2_{2,3}\,\phi^2_{0,0}(v,w)}+\frac{\phi^2_{1,1}\,\phi^2_{3,2}(v,w)}{\phi^2_{2,3}\,\phi^2_{0,0}(v,w)}, \\
1&=-\frac{\phi^2_{3,2}\,\phi^2_{1,0}(v,w)}{\phi^2_{2,2}\,\phi^2_{0,0}(v,w)}+\frac{\phi^2_{0,2}\,\phi^2_{2,0}(v,w)}{\phi^2_{2,2}\,\phi^2_{0,0}(v,w)}+\frac{\phi^2_{1,1}\,\phi^2_{3,3}(v,w)}{\phi^2_{2,2}\,\phi^2_{0,0}(v,w)}.
\end{aligned}
\right\}\quad (\mathrm{A})
$$

In like manner we obtain from the Table, by causing the argument to vanish,

$$
\left.
\begin{aligned}
&\phi^4_{3,3}-\phi^4_{0,0}=\phi^4_{2,0}+\phi^4_{3,2}=\phi^4_{0,2}+\phi^4_{2,3}, \\
&\phi^4_{3,3}-\phi^4_{1,1}=\phi^4_{3,0}+\phi^4_{3,2}=\phi^4_{0,3}+\phi^4_{2,3}, \\
&\phi^4_{3,3}-\phi^4_{2,2}=\phi^4_{3,0}+\phi^4_{0,2}=\phi^4_{0,3}+\phi^4_{2,0},
\end{aligned}
\right\}\quad .\ .\ .\ (\mathrm{B})
$$

$$
\left.
\begin{aligned}
&\phi^2_{3,0}\,\phi^2_{3,3}=\phi^2_{2,0}\,\phi^2_{2,3}+\phi^2_{0,0}\,\phi^2_{0,3}, \\
&\phi^2_{3,0}\,\phi^2_{3,2}=\phi^2_{2,0}\,\phi^2_{2,2}+\phi^2_{0,0}\,\phi^2_{0,2}, \\
&\phi^2_{3,2}\,\phi^2_{3,3}=\phi^2_{2,2}\,\phi^2_{2,3}+\phi^2_{0,2}\,\phi^2_{0,3},
\end{aligned}
\right\}\quad .\ .\ .\ .\ .\ (\mathrm{C})
$$

with twelve similar equations, which will be found on p. 417.

* Because $\phi_{3,1}(v,w)=-\phi_{3,1}(-v,-w)$, which may be proved thus. It is seen at once that $\sum_{-\infty}^{\infty}{}_n\phi(n)=\sum_{-\infty}^{\infty}{}_n\phi(-n)$. Hence $\phi_{3,1}(v,w)=\sum_{-\infty}^{\infty}{}_m p^{m^2}\epsilon^{-2mv}\theta_1(w-2m\mathrm{A},q)$,

or $\phi_{3,1}(-v,-w)=\sum_{-\infty}^{\infty}{}_m p^{m^2}\epsilon^{2mv}\theta_1(-w-2m\mathrm{A},q)=-\phi_{3,1}(v,w)$.

Section 8.—Rosenhain points out that by means of the Table he is able to obtain thirteen out of the fifteen ratios $\frac{\phi_{r,s}}{\phi_{0,0}}$ in terms of any two of them. He selects for that purpose the ratios $\frac{\phi^2_{1,0}(v,w)}{\phi^2_{0,0}(v,w)}$ and $\frac{\phi^2_{2,0}(v,w)}{\phi^2_{0,0}(v,w)}$; he then introduces the new variables x_1 and x_2, and assumes

$$\frac{\phi^2_{1,0}(v,w)}{\phi^2_{0,0}(v,w)}=-k\lambda\mu\,.\,x_1x_2,$$

$$\frac{\phi^2_{2,0}(v,w)}{\phi^2_{0,0}(v,w)}=-\frac{k\lambda\mu}{k_1\lambda_1\mu_1}(1-x_1)(1-x_2),$$

where

$$k^2=\frac{\phi^2_{2,2}\,\phi^2_{2,3}}{\phi^2_{3,2}\,\phi^2_{3,3}},\quad \lambda^2=\frac{\phi^2_{2,0}\,\phi^2_{2,2}}{\phi^2_{3,0}\,\phi^2_{3,2}},\quad \mu^2=\frac{\phi^2_{2,0}\,\phi^2_{2,3}}{\phi^2_{3,0}\,\phi^2_{3,3}},$$

$$k^2_1=\frac{\phi^2_{0,2}\,\phi^2_{0,3}}{\phi^2_{3,2}\,\phi^2_{3,3}},\quad \lambda^2_1=\frac{\phi^2_{0,0}\,\phi^2_{0,2}}{\phi^2_{3,0}\,\phi^2_{3,2}},\quad \mu_1{}^2=\frac{\phi^2_{0,0}\,\phi^2_{0,3}}{\phi^2_{3,0}\,\phi^2_{3,3}};$$

whence it follows from equations (C) that

$$k^2+k^2_1=1,\quad \lambda^2+\lambda^2_1=1,\quad \mu^2+\mu^2_1=1,$$

and from equations (A), that

$$\frac{\phi^2_{3,1}(v,w)}{\phi^2_{0,0}(v,w)}=\frac{\lambda\mu}{k_1\lambda_k\mu_k}(1-k^2x_1)(1-k^2x_2),$$

$$\frac{\phi^2_{3,2}(v,w)}{\phi^2_{0,0}(v,w)}=\frac{\mu k}{\lambda_1\mu_\lambda\lambda_k}(1-\lambda^2x_1)(1-\lambda^2x_2),$$

$$\frac{\phi^2_{3,3}(v,w)}{\phi^2_{0,0}(v,w)}=\frac{k\lambda}{\mu_1\mu_k\mu_\lambda}(1-\mu^2x_1)(1-\mu^2x_2),$$

where

$$\lambda^2_k=k^2-\lambda^2,\quad \mu^2_k=k^2-\mu^2,\quad \mu^2_{\lambda_2}=\lambda^2-\mu^2.$$

Rosenhain also (p. 423) shows how the remaining ratios are to be found. I shall write down three of them, denoting

$$x(1-x)(1-k^2x)(1-\lambda^2x)(1-\mu^2x)\text{ by }\mathrm{R}(x).$$

$$\frac{\phi^2_{0,1}(v,w)}{\phi^2_{0,0}(v,w)}=-\frac{\lambda\mu(1-\lambda^2x_1)(1-\lambda^2x_2)(1-\mu^2x_1)(1-\mu^2x_2)}{\lambda_1\mu_1\lambda_k\mu_k(x_2-x_1)^2}$$
$$\left\{\frac{\sqrt{\mathrm{R}x_1}}{(1-\lambda^2x_1)(1-\mu^2x_1)}\pm\frac{\sqrt{\mathrm{R}x_2}}{(1-\lambda^2x_2)(1-\mu^2x_2)}\right\}^2,$$

$$\frac{\phi^2_{1,2}(v,w)}{\phi^2_{0,0}(v,w)}=\frac{\lambda(1-x_1)(1-x_2)(1-\lambda^2x_1)(1-\lambda^2x_2)}{\mu_1k_1\mu_\lambda k_\lambda(x_2-x_1)^2}$$
$$\left\{\frac{\sqrt{\mathrm{R}x_1}}{(1-x_1)(1-\lambda^2x_1)}\pm\frac{\sqrt{\mathrm{R}x_2}}{(1-x_2)(1-\lambda^2x_2)}\right\}^2,$$

$$\frac{\phi^2_{2,2}(v,w)}{\phi^2_{0,0}(v,w)}=\frac{\lambda x_1x_2(1-\lambda^2x_1)(1^2-\lambda^2x_2)}{\lambda_1\mu_\lambda\lambda_k(x_2-x_1)^2}$$
$$\left\{\frac{\sqrt{\mathrm{R}x_1}}{x_1(1-\lambda^2x_1)}\pm\frac{\sqrt{\mathrm{R}x_2}}{x_2(1-\lambda^2x_2)}\right\}^2.$$

Now if we introduce two new variables, (u) and (u'), and assume them to satisfy the following two equations,

$$du=\frac{1-\lambda^2x_1}{\sqrt{\mathrm{R}x_1}}dx_1+\frac{1-\lambda^2x_2}{\sqrt{\mathrm{R}x_2}}dx_2,$$
$$du'=\frac{1-\mu^2x_1}{\sqrt{\mathrm{R}x_1}}dx_1+\frac{1-\mu^2x_2}{\sqrt{\mathrm{R}x_2}}dx_2,$$

we shall obtain, of course,

$$\frac{dx_1}{du}=\frac{(1-\mu^2x_2)\sqrt{\mathrm{R}x_1}}{\mu^2_\lambda(x_2-x_1)},\quad \frac{dx_1}{du'}=-\frac{(1-\lambda^2x_2)\sqrt{\mathrm{R}x_1}}{\mu^2_\lambda(x_2-x_1)},$$
$$\frac{dx_2}{du}=-\frac{(1-\mu^2x_1)\sqrt{\mathrm{R}x_2}}{\mu^2_\lambda(x_2-x_1)},\quad \frac{dx_2}{du'}=\frac{(1-\lambda^2x_1)\sqrt{\mathrm{R}x_2}}{\mu^2_\lambda(x_2-x_1)},$$

when we remember that

$$(1-\lambda^2x_1)(1-\mu^2x_2)-(1-\lambda^2x_2)(1-\mu^2x_1)=$$
$$(\lambda^2-\mu^2)(x_2-x_1)=\mu^2_\lambda(x_2-x_1).$$

From these equations we are able to obtain

$$\frac{d\sqrt{x_1x_2}}{du},\quad \frac{d\sqrt{x_1x_2}}{du'},\quad \frac{d\sqrt{(1-x_1)(1-x_2)}}{du},\quad \frac{d\sqrt{(1-x_1)(1-x_2)}}{du'}$$

in terms of x_1x_2; also the ratios $\frac{\phi^2_{r,s}(v,w)}{\phi^2_{0,0}(v,w)}$ give us relations, from which we are able to deduce the following expressions:—

$$\sqrt{k\lambda\mu}\,\frac{d\sqrt{x_1x_2}}{du}=\frac{\mu_1\mu_k}{2\mu_\lambda}\,\frac{\phi_{3,3}(v,w)}{\phi_{0,0}(v,w)}\cdot\frac{\phi_{2,3}(v,w)}{\phi_{0,0}(v,w)},$$
$$\sqrt{k\lambda\mu}\,\frac{d\sqrt{x_1x_2}}{du'}=-\frac{\lambda_1\lambda_k}{2\mu_\lambda}\,\frac{\phi_{3,2}(v,w)}{\phi_{0,0}(v,w)}\cdot\frac{\phi_{2,2}(v,w)}{\phi_{0,0}(v,w)},$$
$$\frac{\sqrt{k\lambda\mu}}{\sqrt{k_1\lambda_1\mu_1}}\cdot\frac{d\sqrt{(1-x_1)(1-x_2)}}{du}=-\frac{\mu_k}{2\mu_\lambda}\cdot\frac{\phi_{3,3}(v,w)}{\phi_{0,0}(v,w)}\,\frac{\phi_{1,3}(v,w)}{\phi_{0,0}(v,w)},$$
$$\frac{\sqrt{k\lambda\mu}}{\sqrt{k_1\lambda_1\mu_1}}\cdot\frac{d\sqrt{(1-x_1)(1-x_2)}}{du'}=\frac{\lambda_k}{2\mu_\lambda}\cdot\frac{\phi_{2,2}(v,w)}{\phi_{0,0}(v,w)}\,\frac{\phi_{1,2}(v,w)}{\phi_{0,0}(v,w)}.$$

Section 9.—Rosenhain deduces from the Table the following equation:—

$$\tfrac{1}{2}\phi_{2,0}\,\phi_{3,0}\{\phi_{1,0}(v+v',w+w')\,\phi_{0,0}(v-v',w-w')$$
$$-\phi_{0,0}(v+v',w+w')\,\phi_{1,0}(v-v',w-w')\}$$
$$=\phi_{2,3}(v,w)\,\phi_{3,3}(v,w)\,\phi_{0,3}(v',w')\,\phi_{1,0}(v',w')$$
$$-\phi_{2,2}(v,w)\,\phi_{3,2}(v,w)\,\phi_{1,2}(v',w')\,\phi_{0,2}(v,w).$$

Expanding this in terms of v', and equating the coefficients of v', we have at once

$$\phi_{2,0}\,\phi_{3,0}\,\phi^2_{0,0}(v,w)\frac{d\,.\,\dfrac{\phi_{1,0}(v,w)}{\phi_{0,0}(v,w)}}{dv}=\phi_{0,3}\,\phi'^{(v)}_{1,3}(0,0)\,\phi_{3,3}(v,w)\,\phi_{2,3}(v,w)$$

$$-\phi_{0,2}\,\phi'^{(v)}_{1,2}\,\phi_{3,2}(v,w)\,\phi_{2,2}(v,w);$$

and similarly,

$$\phi_{2,0}\,\phi_{3,0}\,\phi^2_{0,0}(v,w)\frac{d\,.\,\dfrac{\phi_{1,0}(v,w)}{\phi_{0,0}(v,w)}}{dw}=\phi_{0,3}\,\phi'^{(w)}_{1,3}\,\phi_{3,3}(v,w)\,\phi_{2,3}(v,w)$$

$$-\phi_{0,2}\,\phi'^{(w)}_{1,2}\,\phi_{3,2}(v,w)\,\phi_{2,2}(v,w),$$

$$\phi_{2,0}\,\phi_{0,0}\,\phi^2_{0,0}(v,w)\frac{d\,.\,\dfrac{\phi_{2,0}(v,w)}{\phi_{0,0}(v,w)}}{dv}=\phi_{3,3}\,\phi'^{(v)}_{1,3}\,\phi_{3,3}(v,w)\,\phi_{1,3}(v,w)$$

$$-\phi_{3,2}\,\phi'^{(v)}_{1,2}\,\phi_{3,2}(v,w)\,\phi_{1,2}(v,w),$$

$$\phi_{2,0}\,\phi_{0,0}\,\phi^2_{0,0}(v,w)\frac{d\,.\,\dfrac{\phi_{2,0}(v,w)}{\phi_{0,0}(v,w)}}{dw}=\phi_{3,3}\,\phi'^{(w)}_{1,3}\,\phi_{3,3}(v,w)\,\phi_{1,3}(v,w)$$

$$-\phi_{3,2}\,\phi'^{(w)}_{1,2}\,\phi_{3,2}(v,w)\,\phi_{1,2}(v,w);$$

and substituting in these equations the expressions we have obtained in the last section, we have equations of the form

$$\frac{d\sqrt{x_1x_2}}{dv}=\mathrm{A}\frac{d\sqrt{x_1x_2}}{du}+\mathrm{B}\frac{d\sqrt{x_1x_2}}{du'},$$

$$\frac{d\sqrt{x_1x_2}}{dw}=\mathrm{A}'\frac{d\sqrt{x_1x_2}}{du}+\mathrm{B}'\frac{d\sqrt{x_1x_2}}{du'}.$$

where A, B, A′, B′ are certain constants; and we have two similar expressions for

$$\frac{d\sqrt{(1-x_1)(1-x_2)}}{dv},\quad\frac{d\sqrt{(1-x_1)(1-x_2)}}{du},$$

whence we have

$$du=adv+bdw,\quad du'=a'dv+b'dw,$$

by properly choosing

$$a \text{ and } a',\ b \text{ and } b';$$

and therefore, finally,

$$adv+bdw=\frac{1-\lambda^2x_1}{\sqrt{\mathrm{R}x_1}}dx_1+\frac{1-\lambda^2x_2}{\sqrt{\mathrm{R}x_2}}dx_2,$$

$$a'dv+b'dw=\frac{1-\mu^2x_1}{\sqrt{\mathrm{R}x_1}}dx_1+\frac{1-\mu^2x_2}{\sqrt{\mathrm{R}x_2}}dx_2.$$

Hence our formulæ give us the solution of the hyperelliptic differential equations.

Rosenhain, in the last part of his memoir, proves the remarkable equation

$$\int_{-\infty}^{0}\frac{xdx}{\sqrt{\mathrm{R}x}}\int_{0}^{1}\frac{dx}{\sqrt{\mathrm{R}(x)}}-\int_{-\infty}^{0}\frac{dx}{\sqrt{\mathrm{R}x}}\int_{0}^{1}\frac{xdx}{\sqrt{\mathrm{R}(x)}}$$

$$-\int_{\frac{1}{k^2}}^{\frac{1}{\lambda^2}}\frac{xdx}{\sqrt{\mathrm{R}x}}\int_{\frac{1}{\lambda^2}}^{\frac{1}{\mu^2}}\frac{dx}{\sqrt{\mathrm{R}x}}+\int_{\frac{1}{k^2}}^{\frac{1}{\lambda^2}}\frac{dx}{\sqrt{\mathrm{R}x}}\int_{\frac{1}{\lambda^2}}^{\frac{1}{\mu^2}}\frac{xdx}{\sqrt{\mathrm{R}x}}=0,$$

a formula much used by later writers.

Section 10.—We now proceed to consider the method of treating the hyperelliptic functions proposed by Gopel. His justly celebrated paper in the 35th volume of Crelle's Journal presents very few difficulties, which will make our analysis of it shorter and easier. He commences with the sixteen series of which the analogues have been used by Rosenhain, and writes them thus:—

$$\epsilon^{ru^2+r'u'^2}\mathrm{P}\ (u,u')=\Sigma(-1)^{a+b}\epsilon^{r(u+2a\mathrm{K}+2b\mathrm{L})^2+r'(u'+2a\mathrm{K}'+2b\mathrm{L}')^2},$$

$$\epsilon^{ru^2+r'u'^2}\mathrm{P}'\ (u,u')=\Sigma(-1)^{b}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}\mathrm{P}''\ (u,u')=\Sigma(-1)^{a}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}\mathrm{P}'''(u,u')=\Sigma\,.\,1\ .\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}i\mathrm{Q}\ (u,u')=\Sigma(-1)^{a+b}\epsilon^{r(u+r(2a+1)\mathrm{K}+2b\mathrm{L})^2+r'(u'+(2a+1)\mathrm{K}'+2b\mathrm{L}')^2},$$

$$\epsilon^{ru^2+r'u'^2}\ \mathrm{Q}'\ (u,u')=\Sigma(-1)^{b}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}i\mathrm{Q}''\ (u,u')=\Sigma(-1)^{a}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}\ \mathrm{Q}'''(u,u')=\Sigma\,.\,1\ .\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}i\mathrm{R}\ (u,u')=\Sigma(-1)^{a+b}\epsilon^{r(u+2a\mathrm{K}+(2b+1)\mathrm{L})^2+r'(u'+2a\mathrm{K}'+(2b+1)\mathrm{L}')^2},$$

$$\epsilon^{ru^2+r'u'^2}i\mathrm{R}'\ (u,u')=\Sigma(-1)^{b}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}\ \mathrm{R}''\ (u,u')=\Sigma(-1)^{a}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}\ \mathrm{R}'''(u,u')=\Sigma\,.\,1\ .\ \text{(the same expression)},$$

$$\epsilon^{ru^2+'ru'^2}\mathrm{S}\ (u,u')=\Sigma(-1)^{a+b}\epsilon^{r(u+(2a+1)\mathrm{K}+(2b+1)\mathrm{L})^2+r'(u'+(2a+1)\mathrm{K}'+(2b+1)\mathrm{L}')^2}$$

$$\epsilon^{ru^2+r'u'^2}i\mathrm{S}'\ (u,u')=\Sigma(-1)^{b}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}i\mathrm{S}''\ (u,u')=\Sigma(-1)^{a}\ \text{(the same expression)},$$

$$\epsilon^{ru^2+r'u'^2}\ \mathrm{S}'''(u,u')=\Sigma\,.\,1\ .\ \text{(the same expression)}.$$

where Σ applies to (a) and (b) and extends from $-\infty$ to $+\infty$.

It is easily seen that if we change u, u' into $u+4K$, $u'+4K'$, or into $u+4L$, $u'+4L'$, all these series remain unchanged. Hence they are doubly periodic. Moreover their ratios are quadruply periodic; for after removing the common factor $\epsilon^{ru^2+r'u'^2}$, all the exponents of ϵ in numerator and denominator are linear in $u'u'$. Hence it is easy to prove that if u, u' are changed into $u+4A$, $u+4A'$ when

$$A=\frac{\pi L'i}{4r(KL'-K'L)},\quad A'=-\frac{\pi Li}{4r'(KL'-K'L)},$$

or if u', u' are changed into $u+4B$, $u'+4B'$ when we have

$$B=\frac{\pi K'i}{4r(KL'-K'L)},\quad B'=-\frac{\pi Ki}{4r'(KL'-K'L)},$$

the ratios of these functions remain unchanged.

If we suppose u, u' to be augmented by the semiperiods, the quantities P, Q, &c. sometimes remain unchanged, sometimes change their sign. The resulting values are expressed by Göpel in a Table, where the first line gives us the increments of the argument, the remaining lines the resulting signs, thus:—

	$2A$,	$2B$,	$2A+2B$,	$2K$,	$2L$,	$2K+2L$.
P	+	+	+	−	−	+
P′	+	+	+	+	−	−,

and so on for the remaining fourteen series (Göpel, p. 282).

When we suppose $u'u'$ to be augmented by the quarterperiods, P, Q, &c. are changed into other functions of the series, as is expressed in a Table, where the first line, as before, gives us the increments of the arguments, the remaining lines the quantities into which P, Q, &c. are changed, thus:—

	A	B	A+B	K	L	K+L
P	P′	P″	P‴	iQ	iR	S
Q	Q′	Q″	Q‴	iP	$-i$S	−R,

and so on for the remaining fourteen series (Göpel, p. 283).

Göpel next gives a Table of the values of u, u', which cause P, Q, &c. to vanish; thus Q vanishes for 0, B, A+L, K+L, B+L, A+K+L; P for K, L, A+L, B+K, A+K+L, B+K+L; all the functions multiplied by (i) vanish for $u=0$, $u'=0$. I may remark that the vanishing of functions θ has been treated in detail by Riemann, in the 65th volume of Crelle's Journal. We shall refer to the three Tables described in this section as Göpel's first, second, and third Tables.

Section 11.—Göpel next investigates the algebraical relations between the functions P, Q, &c.... In doing so he makes use of the following notation. If in the functions P‴, Q‴, R‴, S‴, $2r$, $2r'$ are written instead of r, r', the four results are denoted by T, U, V, W. When in these functions u and u' vanish, the results are denoted by t, u, v, w; consequently u is used in two different senses in this paper. I shall endeavour to guard against any confusion arising from this. When u, u' are put equal to zero in the functions P, Q, R, S, P′, P″, &c., the results are denoted by ϖ, k, ρ, σ, ϖ', ϖ'', &c.

Then by direct multiplication the following formulæ are arrived at without difficulty:—

$$P^2=tT-uU-vV+wW,$$

and fifteen more precisely similar formulæ for

$$P', Q, \&c. \text{ (p. 287)} \quad \ldots \ldots \quad (1)$$

Putting the arguments u and $u'=0$, we have:—

$$\left.\begin{aligned} &\varpi^2=t^2-u^2-v^2-w^2, \text{ and similarly for } \varpi', \varpi'', \varpi'''; \\ &k'^2=2tu-2vw, \text{ and similarly for } \rho''^2, \sigma^2; \\ &k'''^2=2tu+2vw, \text{ and similarly for } \rho'''^2, \sigma'''^2; \\ &k, k'', \rho, \rho', \sigma', \sigma'' \text{ vanish.} \end{aligned}\right\} \quad \ldots \quad (2)$$

From these we easily deduce the following:—

$$\left.\begin{aligned} &\varpi'''^4-\varpi'^4 \quad =\rho'''^4+\sigma^4=\rho''^4+\sigma'''^4, \\ &\varpi'''^4-\varpi''^4 \quad =\sigma'''^4+k'^4=\sigma^4+k'''^4, \\ &\varpi^2\varpi'''^2-\varpi'^2\varpi''^2=\sigma^2\sigma'''^2, \quad \varpi^2k'''^2-\varpi''^2k'^2=\rho'''^2\sigma^2, \\ &\varpi^2\rho'''^2-\varpi'^2\rho''^2=k'''^2\sigma^2, \quad \varpi^2\sigma'''^2-\varpi'''^2\sigma^2=k'^2\rho''^2, \end{aligned}\right\} \quad \ldots \quad (3)$$

with many similar formulæ (p. 288).

From formulæ (1) we easily see that we have an expression of the form

$$P^2=\alpha P'^2+\beta S'^2+\gamma P''^2+\delta S''^2;$$

by putting the arguments u, u' equal to zero and the quarterperiods, we determine α, β, γ, δ, and we find

$$(\varpi'^4-\varpi''^4)P^2=-\rho''^2\rho'''^2P'^2+\rho''^2k'''^2S'^2+k'^2k'''^2P''^2-k'^2\rho'''^2S''^2,$$

with similar formulæ for S^2, P'''^2, &c., also in terms of

$$P'^2, S'^2, P''^2, S''^2. \quad \ldots \ldots \quad (4)$$

Göpel next investigates the relations which exist between the products PS, P′S′. By means of Table 1 he proves very easily that such relation must be of the form

$$aPS+bP'S'+cP''S''+dP'''S'''+eQR+fQ'R'+gQ''R''+hQ'''R'''=0;$$

and then, by the help of the second Table, he proves that this equation gives rise to the two following:—

$$aPS+dP'''S'''+eQR+hQ'''R'''=0,$$

$$bP'S'+cP''S''+fQ'R'+gQ''R''=0.$$

By putting the arguments u, $u'=0$, and also, making use of equations (3) of this section, we obtain the following two equations derived from the second of those we have just written down:—

$$k'''\rho'''Q'R'=\varpi'''\sigma'''P'S'-\varpi\sigma P''S'',$$

$$k'''\rho'''Q''R''=-\varpi\sigma P'S'+\varpi'''\sigma'''P''S''.$$

Squaring the first of these equations and making use of equations (4),

$$
\begin{aligned}
&P'^4 + S'^4 - \frac{k'''^4+\rho'''^4}{k'''^2\rho'''^2}P'^2S'^2 - \frac{\varpi'^4+\varpi''^4}{\varpi'^2\varpi''^2}(P'^2P''^2 + S'^2S''^2) \\
&\quad + \frac{k'^4+\rho''^4}{k'^2\rho''^2}(P'^2S'''^2 + P''^2S'^2) - \frac{k'''^4+\rho'''^4}{k'''^2\rho'''^2}P''^2S''^2 \\
&\quad + P''^4 + S''^4 - \frac{2\varpi\sigma\varpi'''\sigma'''(\varpi'^4-\varpi''^4)^2}{\varpi'^2\varpi^2k'^2\rho''^2k'''^2\rho'''^2}P'S'P''S''=0. \quad . \quad . \quad . \quad . \quad . \qquad \text{(A)}
\end{aligned}
$$

In a similar manner the following equations are obtained:—

$$
\begin{aligned}
&\left(\frac{\varpi'^4-\varpi''^4}{k'''^2\rho'''^2}\right)(P'''^2S'''^2 - P^2S^2) \\
&=\left\{P'^4 - \frac{k'''^4+\rho'''^4}{k'''^2\rho'''^2}P'^2S'^2 + S'^4\right\} - \left\{P''^4 - \frac{k'''^4+\rho'''^4}{k'''^2\rho'''^2}P''^2S''^2 + S''^4\right\}, \quad . \qquad \text{(B)}
\end{aligned}
$$

$$
\begin{aligned}
&(P'''S''' + PS)^2 \\
&\qquad = \frac{(\varpi'''\sigma'''+\varpi\sigma)^2}{\varpi'^2\varpi''^2}(P'^2P''^2 + S'^2S''^2) - \frac{k'''^2\rho'''^2}{k'^2\rho''^2}(P'^2S''^2 + P''^2S'^2) \\
&\qquad\quad + 2\left(\frac{\varpi\sigma\varpi'''\sigma'''(k'^4+\rho''^4)}{\varpi'^2\varpi''^2k'^2\rho''^2} - \frac{\varpi^2\varpi'''^2+\sigma^2\sigma'''^2}{\varpi'^2\varpi''^2}\right)P'P''S'S'', \quad . \quad . \quad . \qquad \text{(C)}
\end{aligned}
$$

$$
\begin{aligned}
&(P'''S''' - PS)^2 = \frac{(\varpi'''\sigma'''-\varpi\sigma)^2}{\varpi'^2\varpi''^2}(P'^2P''^2 + S'^2S''^2) \\
&- \frac{k'''^2\rho'''^2}{k'^2\rho''^2}(P'^2S''^2 + P''^2S'^2) + 2\left(\frac{\varpi\sigma\varpi'''\sigma'''(k'^4+\rho''^4)}{\varpi'^2\varpi''^2k'^2\rho''^2} + \frac{\varpi^2\varpi'''^2+\sigma^2\sigma'''^2}{\varpi'^2\varpi''^2}\right)P'P''S'S''. \quad \text{(D)}
\end{aligned}
$$

Section 12.—Equation (A) gives a relation between P', S', P'', S''. Göpel proves that no other relation can exist, of a purely algebraical nature, between these quantities (p. 292). He consequently investigates the relations which exist between the differentials of those functions in the following way:—

Putting

$$M_1 = \epsilon^{r(u+2a_1K+2b_1L)^2 \dots},$$

$$M = \epsilon^{r(u+(2a+1)K+(2b+1)L)^2 \dots},$$

we have

$$MM_1 = \epsilon^{2r\{(\eta_1+\frac{1}{2})K+(\theta_1+\frac{1}{2})L\}^2+\dots}\,\epsilon^{2r\{u+(\eta+\frac{1}{2})K+(\theta+\frac{1}{2})L\}^2+\dots},$$

where

$$a+a_1=\eta, \quad b+b_1=\theta,$$

$$a-a_1=\eta_1, \quad b-b_1=\theta;$$

this is easily seen if we remember that

$$(a_1-a_1)^2+(a-a_1)+\tfrac{1}{4}+(a+a_1)^2+(a+a_1)+\tfrac{1}{4}=2a^2+2a_1^2+2a+\tfrac{1}{2},$$

and also that

$$2(a-a_1+\tfrac{1}{2})(b-b_1+\tfrac{1}{2})+2(a+a_1+\tfrac{1}{2})(b+b_1+\tfrac{1}{2})=4a_1b_1+4ab+2a+2b+1;$$

and then it is seen without much difficulty that

$$\epsilon^{2ru^2+2r'u'^2} i(P'dS'-S'dP')=a_1T_1+b_1U_1+c_1V_1+d_1W_1,$$

where T_1, U_1, V_1, W_1 are the values of

$\Sigma\epsilon^{2r(u+(\eta+\frac{1}{2})K+(\theta+\frac{1}{2})L)^2}$ when θ is even and η is even, θ even and η odd, &c.

Hence we find

$$P'dS'-S'dP'=aPS+bP'''S'''+cQR+dQ'''R'''+a_1P'S'+b_1P''S''$$
$$+c_1Q'R'+d_1Q''R'',$$

where such quantities as $P'Q$ are excluded according to the law given in page 290, and a, b, &c. are of the form $fdu+f'du'$, where f and f' are constants. But since $Q'R'$, $Q''R''$ can be expressed in terms of $P'S'$ and $P''S''$, and also QR, $Q'''R'''$ in terms of PS, $P'''S'''$, we shall have

$$P'dS'-S'dP'=aPS+bP'''S'''+a_1P_1S_1+b_1P''S''.$$

Putting $u+K+L$ for u, we have

$$P'dS'-S'dP'=aPS+bP'''S'''-a_1P'S'-b_1P''S'';$$

whence

$$P'dS'-S'dP'=aPS+bP'''S''';$$

and changing u into $u+A+B$,

$$P''dS''-S''dP''=aP'''S'''+bPS,$$

the coefficients are easily determined; and we have, finally,

$$P'dS'-S'dP'=\frac{\rho''dk''}{\rho'''k'''}PS+\frac{k'd\rho'}{k'''\rho'''}P'''S''',$$

$$P''dS''-S''dP''=\frac{\rho''dk''}{\rho'''k'''}P'''S'''+\frac{k'd\rho'}{k'''\rho'''}PS.$$

Section 13.—We shall now show that from these equations the hyper-elliptic differential equations can be deduced. We shall give the outline of the calculation, referring the reader for the details to the original memoir. From the equations last given, we have

$$\frac{(P'dS'-S'dP')+(P''dS''-S''dP'')}{P'''S'''+PS}=\frac{k'd\rho'+\rho''dk''}{k'''\rho'''}=d\mu,$$

$$\frac{(P'dS'-S'dP')-(P''dS''-S''dP'')}{P'''S'''-PS}=\frac{k'd\rho'-\rho''dk''}{k'''\rho'''}=d\nu.$$

Putting

$$\frac{S'}{P'}=p,\qquad \frac{S''}{P''}=q,\qquad \frac{P'}{P''}=s,$$

$$\frac{P'''S'''+PS}{P'P''}=\phi,\qquad \frac{P'''S'''-PS}{P'P''}=\psi,$$

the last equations are transformed into the following :—

$$\frac{sdp+\frac{1}{s}dq}{\phi}=d\mu, \qquad \frac{sdp-\frac{1}{s}dq}{\psi}=d\nu. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Also, using the same notation, the last four equations of section 11 may be written thus:—

$$(1-2Ep^2+p^4)s^4-2(F(1+p^2q^2)-C(p^2+q^2)+2Dpq)s^2$$
$$+(1-2Eq^2+q^4)=0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$2\sqrt{E^2-1}\,.\,\phi\psi=(1-2Ep^2+p^4)s^2-(1-2Eq^2+q^4)\frac{1}{s^2}, \quad . \quad . \quad . \quad . \quad (3)$$

$$\phi^2=(b+b_1)(1+p^2q^2)-a(p^2+q^2)+2(c-c_1)pq, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$\psi^2=(b-b_1)(1+p^2q^2)-a(p^2+q^2)+2(c+c_1)pq, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where E, F, a, b, &c. are constants, whose values will be found in p. 299; hence, by addition, we find

$$s^2=\frac{F(1+p^2q^2)-C(p^2+q^2)+2Dpq+\sqrt{E^2-1}\,.\,\phi\psi}{1-2Ep^2+p^2},$$

$$\frac{1}{s^2}=\frac{F(1+p^2q^2)-C(p^2+q^2)+2Dpq-\sqrt{E^2-1}\,.\,\phi\psi}{1-2Eq^2+q^4}.$$

Moreover equations (1) may be written

$$\frac{\left(s\Delta p+\frac{\Delta q}{s}\right)}{\phi}\left(\frac{dp}{2\Delta p}+\frac{dq}{2\Delta q}\right)+\frac{\left(s\Delta p-\frac{\Delta q}{s}\right)}{\phi}\left(\frac{dp}{2\Delta p}+\frac{dq}{2\Delta q}\right)=d\mu,$$

$$\frac{\left(s\Delta p-\frac{\Delta q}{s}\right)}{\psi}\left(\frac{dp}{2\Delta p}+\frac{dq}{2\Delta q}\right)+\frac{\left(s\Delta p+\frac{\Delta q}{s}\right)}{\psi}\left(\frac{dp}{2\Delta p}-\frac{dq}{2\Delta q}\right)=d\nu.$$

Putting here $$p=\frac{y\Delta z+z\Delta y}{1-y^2z^2}, \qquad q=\frac{y\Delta z-z\Delta y}{1-y^2z^2},$$

where also

$$\Delta y=\sqrt{1-Ey^2+y^4}, \qquad \Delta z=\sqrt{1-Ez^2+z^4},$$

and remembering that

$$\frac{dp}{\Delta p}=\frac{dy}{\Delta y}+\frac{dz}{\Delta z}, \qquad \frac{dq}{\Delta q}=\frac{dy}{\Delta y}-\frac{dz}{\Delta z},$$

we separate the variables, and obtain

$$\sqrt{\{2(F+1)\}}\frac{dy}{\sqrt{(1-2Ey^2+y^4)}}\cdot\sqrt{\left(\frac{1-2E_2y^2+y^4}{1-2E_1y^2+y^4}\right)}$$
$$+\sqrt{\{2(F-1)\}}\frac{dz}{\sqrt{(1-2Ez^2+z^4)}}\cdot\sqrt{\left(\frac{1-2E_4z^2+z^4}{1-2E_3z^2+z^4}\right)}=\sqrt{b+b_1}\,.\,d\mu,$$

$$\sqrt{\{2(F-1)\}}\frac{dy}{\sqrt{(1-2Ey^2+y^4)}}\cdot\sqrt{\left(\frac{1-2E_1y^2+y^4}{1-2E_2y^2+y^4}\right)}$$
$$+\sqrt{\{2(F+1)\}}\frac{dz}{\sqrt{(1-2Ez^2+z^4)}}\sqrt{\frac{1-2E_3z^2+z^4}{1-2E_4z^2+z^4}}=\sqrt{b-b_1}d\nu,$$

where

$$\frac{C-E-D}{F-1}=E_1,\quad \frac{C+E-D}{F+1}=E_2,\quad \frac{C+E+D}{F+1}=E_3,\quad \frac{C-E+D}{F-1}=E_4.$$

If we put

$$z^2=\frac{\alpha^2-y'^2}{1-\alpha^2y'^2},$$

where α is a root of the equation

$$1-2Ee^2+e^4=0,$$

we are able to deduce

$$\sqrt{(2(F-1))}\frac{dz}{\Delta z}\sqrt{\left(\frac{1-2E_4z^2+z^4}{1-2E_3z^2+z^4}\right)}=\sqrt{(2(F+1))}\frac{dy'}{\Delta y'}\sqrt{\left(\frac{1-2E_2y'^2+y'^4}{1-2E_1y'^2+y'^4}\right)}$$

By this substitution Göpel remarks that we obtain an equation perfect in symmetrical form with respect to the variables. And, lastly, putting

$$x=\left(\frac{1-y^2}{1+y^2}\right)^2,\quad x'=\left(\frac{1-y'^2}{1+y'^2}\right)^2,$$

he equations become

$$\frac{dx\sqrt{1-m_2x}}{\sqrt{(x(1-x)(1-mx)(1-m_1x))}}+\frac{dx'\sqrt{1-m_2x'}}{\sqrt{(x'(1-x')(1-mx')(1-m_1x'))}}$$

$$=2\sqrt{b+b_1}\sqrt{\frac{(1-E)(1-E_1)}{(1+F)(1-E_2)}}d\mu,$$

$$\frac{dx\sqrt{1-m_1x}}{\sqrt{(x(1-x)(1-mx)(1-m_2x))}}+\frac{dx'\sqrt{1-m_1x'}}{\sqrt{(x'(1-x')(1-mx')(1-m_2x'))}}$$

$$=2\sqrt{b-b_1}\sqrt{\left(\frac{(1-E)(1-E_2)}{(F-1)(1-E_1)}\right)}d\nu$$

when

$$m=\frac{E+1}{E-1},\quad m_1=\frac{E_1+1}{E_1-1},\quad m_2=\frac{E_2+1}{E_2-1}.$$

Hence the solution of the hyperelliptic differential equations of the first order is easily obtained.

Section 14.—In connexion with this part of the Report we may consider a very beautiful method of integrating a certain system of hyperelliptic differential equations given by Jacobi in the 32nd volume of Crelle's Journal.

Let

$$Yx^n-Y_1x^{n-1}+Y_2x^{n-2}\ldots\pm Y_n=Ry^2+2Sy+T=0$$

be an equation represented in two different ways, where Y, Y_1.... are, of course, of the second, and R, S, T of the nth order in y and x respectively. Then this equation, differentiated, manifestly gives

$$\frac{dx}{Ry+S}+\frac{2dy}{nYx^{n-1}-(n-1)Y_1x^{n-2}\ldots\ldots+Y_{n-1}}=0.$$

Let x_m be one of the n roots of the algebraical equation; then this gives us

$$\frac{dx_m}{\sqrt{S_m^2-R_mT_m}}+\frac{2dy}{Y(x_m-x_1)(x_m-x_2)\ldots\ldots(x_m-x_n)}=0,$$

which, if

$$f(x)=S^2-RT,$$

gives rise to the system of differential equations

$$\frac{dx_1}{\sqrt{fx_1}}+\frac{dx_2}{\sqrt{fx_2}}+\frac{dx_3}{\sqrt{fx_3}}+\ldots\frac{dx_n}{\sqrt{fx_n}}=0,$$

$$\frac{x_1dx_1}{\sqrt{fx_1}}+\frac{x_2dx_2}{\sqrt{fx_2}}+\frac{x_3dx_3}{\sqrt{fx_3}}+\ldots\frac{x_ndx}{\sqrt{fx_n}}=0,$$

$$\&c. \qquad =\ldots$$

$$\frac{x_1^{n-2}dx_1}{\sqrt{fx_1}}+\frac{x_2^{n-2}dx_2}{\sqrt{fx_2}}+\ldots+\frac{x_n^{n-2}dx_n}{\sqrt{fx_n}}=0.$$

Now let

$$f(x)=M^2+N^2-L^2,$$

where M, N, L are three rational and entire functions of the nth order. But since

$$M^2+N^2-L^2=M^2-(L+N)(L-N),$$

$x_1, x_2 \ldots, x_n$ may be regarded as the n roots of the equation

$$(L+N)y^2+2My+(L-N)=0,$$

or

$$L(1+y^2)+2My+N(1-y^2)=0,$$

which may be written

$$L=M\sin\theta+N\cos\theta,$$

where θ is a new variable. Substituting $x_1, x_2, x_3\ldots$ for x in this equation, we obtain a system of equations which may be regarded as the complete integral of the above system.

Part III. *On the Transformation of Hyperelliptic Functions.*

In considering the papers of Königsberger on the transformation of hyperelliptic functions in the 64th and 65th volumes of Crelle's Journal, it will be convenient in this Report to follow his division as to sections. We commence with the paper in the 64th volume.

Section 1.—Königsberger assumes the following connexion between two sets of variables:—

$$u_1=2K_{1,1}v_1+2K_{1,2}v_2+\ldots+2K_{1,\rho}v_\rho,$$
$$u_2=2K_{2,1}v_2+2K_{2,2}v_2+\ldots+2K_{2,\rho}v_\rho,$$
$$\alpha=\ldots$$
$$u_\rho=2K_{\rho,1}v_1+2K_{\rho,2}v_2+\ldots+2K_{\rho,\rho}v_\rho,$$
$$v_1=G_{1,1}u_1+G_{2,2}u_2+\ldots+G_{\rho,1}u_{\rho1},$$
$$v_2=G_{1,2}u_1+G_{2,2}u_2+\ldots+G_{\rho,2}u_\rho,$$
$$\alpha=\ldots$$
$$v_\rho=G_{1,\rho}u_1+G_{2,\rho}u_2+\ldots+G_{\rho,\rho}u_\rho;$$

also

$$\tau_{\alpha,\beta}=2iG_{1,\alpha}K'_{1,\beta}+2iG_{2,\alpha}K'_{2,\beta}+\ldots\ldots+2iG_{\rho,\alpha}K'_{\rho,\beta};$$

and $\tau_{\alpha,\beta}=\tau_{\beta,\alpha}$; then function θ is defined by the following equations:—

$$\theta(v_1+p_1,\ v_2+p_2,\ \ldots\ldots v_\rho+p_\rho)\ =\theta(v_1v_2\ldots\ldots v_\rho),\quad \ldots\ldots \quad (1)$$

$$\theta(v_1+\tau_{1,\alpha}v_2+\tau_{2,\alpha}\ldots\ldots v_\rho+\tau_{\rho,\alpha})=\epsilon^{-(2v_\alpha+\tau_{\alpha,\alpha})\pi i}\theta(v_1v_2\ldots\ldots v_\rho),\ .\ .\quad (2)$$

whence

$$\theta(v_1v_2\ldots\ldots v_\rho)=$$

$$\Sigma\{\epsilon^{(\nu_1(2v_1+\nu_1\tau_{1,1}+\ldots+\nu_\rho\tau_{1,\rho})+\nu_2(2v_2+\nu_1\tau_{2,1}+\ldots\nu_\rho\tau_{2,\rho})+\ldots\nu_\rho(2v_\rho+\nu_1\tau_{\rho,1}+\ldots\nu_\rho\tau_{\rho,\rho}))\pi i}\}\ (3)$$

It will be observed that these assumptions coincide with those of Weierstrass (Crelle, xlvii. p. 303), and which we have given in the Report (Brighton) for 1872, p. 345, by putting in the formulæ of Weierstrass $2\pi v_1$, $2\pi v_2\ldots\ldots 2\pi v_\rho$ for $v_1, v_2\ldots\ldots v_\rho$, and $2G_{1,1}\ldots$ for $G_{1,1}$; then it will be found that Jc and θ are equivalent.

We easily obtain from (2),

$$\theta(v_1+n\tau_{1,\alpha},\quad v_2+n\tau_{2,\alpha},\ \ .\ \ .)=\epsilon^{-n(v_\alpha+n\tau_{\alpha,\alpha})\pi i}\theta(v_1v_2\ldots\ .v_\rho),$$

and

$$\theta(v_1+n_1\tau_{1,1}+n_2,\ \tau_{1,2},\ v_2+n_1\tau_{2,1}+n_2\tau_{2,2},\ \ldots\ldots)$$
$$=\epsilon^{-n_1(2v_1+n_1\tau_{1,1}+n_2\tau_{1,2})-n_2(2v_2+n_1\tau_{2,1}+n_2\tau_{2,2})}\theta(v_1v_2\ldots\ldots v_\rho);$$

and writing

$$\tau_\alpha=n_1\tau_{\alpha,1}+n_2\tau_{\alpha,2}+\ldots\ldots,$$

$$\theta(v_1+\tau_1,\ v_2+\tau_2,\ \ldots\ldots v_\rho+\tau_\rho)=\epsilon^{-\Sigma n_\nu(2v_\nu+\tau_\nu)\pi i}\theta(v_1v_2\ldots\ldots v_\rho).$$

This assumes, of course, that $n_1, n_2, \ldots\ldots n_\rho$ are integers; when they are not, Königsberger assumes another transcendent, as follows:—

$$\epsilon^{\Sigma n_\nu(2v_\nu+\tau_\nu)\pi}{}_\nu\theta(v_1+\tau_1,\ v_2+\tau_2,\ \ldots\ldots v_\rho+\tau_\rho),$$

and calls it $\theta(v_1v_2\ldots\ldots v_\rho, n_1n_2\ldots\ldots n_\rho)$.

Then we shall have, if $\tau'_\nu=n'_1\tau_{\nu,1}+n'_2\tau_{\nu,2}+\ldots\ldots n'_\rho\tau_{\nu,\rho})$,

$$\theta(v_1+\tau'_{1,1}v_2+\tau'_{2,1}\ldots\ldots n_1n_2\ldots\ldots n_\rho)=\epsilon^{\Sigma n_\nu(2v_\nu+2\tau'_\nu+\tau_\nu)\pi i}\theta(v_1+\tau'_1+\tau_1\ldots\ldots)$$
$$\epsilon^{\Sigma n_\nu(2v_\nu+2\tau'_\nu+\tau_\nu)}\ \epsilon^{-\Sigma(n_\nu+n'_\nu)(2v_\nu+\tau_\nu+\tau'_\nu)}\theta(v_1v_2\ldots\ldots v_\rho),$$

(remembering that $\Sigma n'_\nu\tau_\nu=\Sigma n_\nu\tau'_\nu$)

$$=\epsilon^{-n'(2v_\nu+\tau'_\nu)\pi i}\theta(v_1,\ v_2\ldots\ldots v_\rho,\ n_1+n'_1,\ n_2+n'_2\ldots\ldots).$$

Königsberger furthermore assumes transcendents with the notation:—

$$\theta(v_1v_2\ldots\ldots v_\rho)_\lambda=\theta(v_1+\tfrac{1}{2}m_1^\lambda\ldots\ldots v_\rho+\tfrac{1}{2}m_\rho^\lambda;\ \tfrac{1}{2}n_1^\lambda\ldots\ldots\tfrac{1}{2}n_\rho^\lambda);$$

also

$$\theta(v_1\ldots\ldots v_\rho)_{\lambda,\mu}=\theta_1(v_1+\tfrac{1}{2}m_1^\omega\ldots\ldots v_\rho+\tfrac{1}{2}m_\rho^\omega;\ \tfrac{1}{2}m_1^\omega\ \ldots\ldots\ n_\rho^\omega),$$

where $m_\nu^\omega\equiv m_\nu^\lambda+m_\nu^\mu$ (mod. 2), $n_\nu^\omega\equiv n_\nu^\lambda+n_\nu^\mu$ (mod. 2), and n_1^λ and n_1^μ &c. are given by the Table, p. 20.

Section 2.—We here supply the proof of the leading theorem given at the commencement of this section:—

$$\theta(v_1+\tfrac{1}{2}\varpi_1^\mu,\quad v_2+\tfrac{1}{2}\varpi_2^\mu,\quad v_3+\tfrac{1}{2}\varpi_3^\mu\ldots\ldots v_\rho+\tfrac{1}{2}\varpi_\rho^\mu)_\lambda$$

$$=\theta(v_1+\tfrac{1}{2}m_1^\lambda+\tfrac{1}{2}\varpi_1^\nu,\ v_2+\tfrac{1}{2}m_2^\lambda+\tfrac{1}{2}\varpi_2^\mu,\ \ldots\ldots v_\rho+\tfrac{1}{2}m_1^\lambda+\tfrac{1}{2}\varpi_\rho^\mu,\ \tfrac{1}{2}n_1^\lambda,\ \tfrac{1}{2}n_2^\lambda,\ \ldots\ \tfrac{1}{2}n^\lambda),$$

$$=\epsilon^{\Sigma\frac{1}{2}n_\nu^\lambda(2v_\nu+m_\nu^\lambda+\varpi_\nu^\mu+\tau_\nu)\pi i},\quad \theta(v_1+\tau_1+\tfrac{1}{2}m_1^\lambda+\tfrac{1}{2}\varpi_1^\mu,\quad v_2+\tau_2+\tfrac{1}{2}m_2^\lambda+\tfrac{1}{2}\varpi_2^\mu,$$

$$\ldots\ldots v_\rho+\tau_\rho+\tfrac{1}{2}m_\rho^\lambda+\tfrac{1}{2}\varpi_\rho^\mu)$$

$$=\epsilon^{\Sigma\frac{1}{2}n_\nu^\lambda(2v_\nu+m_\nu^\lambda+\varpi_\nu^\mu+\frac{1}{2}n_1^\lambda\tau_{\nu,1}+\frac{1}{2}n_2^\lambda\tau_{\nu,2}+\ldots\ldots)\pi i}.$$

$$\theta(v_1+\Sigma\tfrac{1}{2}n_\nu^\lambda\tau_{1,\nu}+\tfrac{1}{2}m_1^\lambda+p_1+\tfrac{1}{2}m_1^\mu+\Sigma q_\nu\tau_{1,\nu}+\Sigma\tfrac{1}{2}n_\nu^\mu\tau_{1,\nu}$$

$$v_2+\Sigma\tfrac{1}{2}n_\nu^\lambda\tau_{2,\nu}+\tfrac{1}{2}m_2^\lambda+p_2+\tfrac{1}{2}m_2^\mu+\Sigma q_\nu\tau_{2,\nu}+\Sigma\tfrac{1}{2}n_\nu^\mu\tau_{2,\nu},$$

$$v_3+\Sigma\tfrac{1}{2}n_\nu^\lambda\tau_{3,\nu}+\tfrac{1}{2}m_3^\nu+p_3+\tfrac{1}{2}m_3^\mu+\Sigma q_\nu\tau_{3,\nu}+\Sigma\tfrac{1}{2}n_\nu^\mu\tau_{3,\nu}\ldots\ldots)$$

$$=\epsilon^{\Sigma\frac{1}{2}n_\nu^\lambda(2v_\nu+m_\nu^\lambda+\varpi_\nu^\mu+\frac{1}{2}n_1^\lambda\tau_{\nu,1}+\frac{1}{2}n_1^\lambda\tau_{\nu,2}+\ldots)\pi i}.$$

$$\epsilon^{-\Sigma q_\nu(2v_\nu+\Sigma n_\sigma^\lambda\tau_{\nu,\sigma}+m_\nu^\lambda+m_\nu^\mu+\Sigma n_\nu^\mu\tau_{\nu,\sigma}+\Sigma q_\sigma\tau_{\nu,\sigma})\pi i}.$$

$$\theta(v_1+\Sigma\tfrac{1}{2}n_\nu^\lambda\tau_{1,\nu}+\tfrac{1}{2}m_1^\lambda+\tfrac{1}{2}m_1^\mu+\Sigma\tfrac{1}{2}n_\nu^\mu\tau_{1,\nu}$$

$$v_2+\Sigma\tfrac{1}{2}n_\nu^\lambda\tau_{2,\nu}+\tfrac{1}{2}m_2^\lambda+\tfrac{1}{2}m_2^\mu+\Sigma\tfrac{1}{2}n_\nu^\mu\tau_{2,\nu},$$

$$v_3+\Sigma\tfrac{1}{2}n_\nu^\lambda\tau_{3,\nu}+\tfrac{1}{2}m_3^\lambda+\tfrac{1}{2}m_3^\mu+\Sigma\tfrac{1}{2}n_\nu^\mu\tau_{3,\nu}\quad\ldots\quad)$$

$$=\epsilon^{\Sigma\frac{1}{2}n_\nu^\lambda(2v_\nu+\varpi_\nu^\mu+m_\nu^\lambda+\frac{1}{2}n_1^\lambda\tau_{\nu,1}+\frac{1}{2}n_2^\lambda\tau_{\nu,2}+\ldots)\pi i}.$$

$$\epsilon^{-\Sigma q_\nu(2v_\nu+\Sigma n_\sigma^\lambda\tau_{\nu,\sigma}+m_\nu^\lambda+m_\nu^\mu+\Sigma n_\sigma^\mu\tau_{\nu,\sigma}+\Sigma q_\sigma\tau_{\nu,\sigma})\pi i}.$$

$$\epsilon^{-\Sigma\frac{1}{2}(n_\nu^\lambda+n_\nu^\mu)(2v_\nu+m_\nu^\lambda+m_\nu^\mu+\frac{1}{2}\Sigma(n_\sigma^\lambda+n_\sigma^\mu),\ \tau_{\nu,\sigma})\pi i}.$$

$$\theta(v_1v_2\ldots v_\rho)_\omega,$$

(remembering that $m_\nu^\omega\equiv m_\nu^\lambda+m_\nu^\mu$ (mod. 2))

$$=\epsilon^{\Sigma\frac{1}{2}n_\nu^\lambda(2v_\nu+m_\nu^\lambda+2p_\nu+m_\nu^\mu+\Sigma(2q_\sigma+n_\sigma^\mu)\tau_{\nu,\sigma})\pi i}.$$

$$\epsilon^{-\Sigma\frac{1}{2}(n_\nu^\lambda+n_\nu^\mu)(2v_\nu+m_\sigma^\lambda+m_\sigma^\mu+\frac{1}{2}\Sigma(n_\sigma^\lambda+n_\sigma^\mu)\tau_{\nu,\sigma})\pi i}.$$

$$\epsilon^{-\Sigma q_\nu(2v_\nu+\Sigma n_\sigma^\lambda\tau_{\nu,\sigma}+m_\nu^\lambda+m_\nu^\mu+\Sigma n_\sigma^\mu\tau_{\nu,\sigma}+\Sigma q_\sigma\tau_{\nu,\sigma})\pi i}.$$

$$\epsilon^{\Sigma\frac{1}{2}n_\nu^\lambda(\Sigma\frac{1}{2}n_\sigma^\lambda\tau_{\nu,\sigma})\pi i}.\quad\theta(v_1v_2\ldots\ldots v_\rho)_\omega$$

$$=\epsilon^{\frac{1}{2}n_\nu^\lambda(m_\nu^\lambda+2p_\nu+m_\nu^\mu)\pi i}.\quad\epsilon^{-\Sigma\frac{1}{2}(n_\nu^\lambda+n_\nu^\mu)(m_\nu^\lambda+m_\nu^\mu)\pi i}.$$

$$\epsilon^{-\Sigma q_\nu(m_\nu^\lambda+m_\nu^\mu)\pi i}.\quad\theta(v_1v_2\ldots\ldots v_\rho)_\omega.$$

$$.\,\epsilon^{-\Sigma(q_\nu+\frac{1}{2}n_\nu^\mu)(2v_\nu+(q_1+\frac{1}{2}n_1^\mu)\tau_{\nu,1}+(q_2+\frac{1}{2}n_2^\mu)\tau_{\nu,2}+\ldots)\pi i}$$

(remembering that $\Sigma q_\nu\Sigma n_\sigma^\mu\tau_{\nu,\sigma}=\frac{1}{2}\Sigma q_\sigma\Sigma n_\nu^\mu\tau_{\nu,\sigma}+\frac{1}{2}\Sigma q_\nu\Sigma n_\sigma^\mu\tau_{\nu,\sigma}$)

$$=\epsilon^{(-1)\Sigma_\nu(p_\nu n_\nu^\lambda+q_\nu m_\nu^\omega)\pi i}\,.\,\epsilon^{-\Sigma_\nu\frac{1}{2}n_\nu^\mu(m_\nu^\lambda+m_\nu^\mu)\pi i}.\ \theta(v_1v_2\ldots\ldots v_\rho)_\omega.$$

$$\epsilon^{-\Sigma(q_\nu+\frac{1}{2}n_\nu^\mu)(2v_\nu+(q_1+\frac{1}{2}n_1^\mu)\tau_{\nu,1}+(q_2+\frac{1}{2}n_2^\mu)\tau_{\nu,2}+\ldots)\pi i}.$$

a result substantially the same as Königsberger's, although it seems to me that there is a misprint in his paper.

To illustrate the Table at the bottom of page 22, I observe as follows:— Referring to the Table at the foot of page 20, we have

$$\begin{aligned}\theta(v_1v_2)_{0,3}&=\theta(v_1+\tfrac{1}{2}m_1^0+\tfrac{1}{2}m_1^3, \quad v_2+\tfrac{1}{2}m_2^0+\tfrac{1}{2}m_2^3, \quad \tfrac{1}{2}n_1^0+\tfrac{1}{2}n_1^3, \quad \tfrac{1}{2}n_2^0+\tfrac{1}{2}n_2^3)\\ &=\theta(v_1-\tfrac{1}{2}+0, \quad v_2-\tfrac{1}{2}-\tfrac{1}{2}, \quad \tfrac{1}{2}0+\tfrac{1}{2}0, \quad \tfrac{1}{2}0+\tfrac{1}{2})\\ &=\theta(v_1-\tfrac{1}{2}, \quad v_2, \quad 0, \quad \tfrac{1}{2}),\end{aligned}$$

which agrees with the expression given in the Table by Königsberger. The reader is requested to notice that Königsberger writes $\theta(v_1v_2)_5=\theta(v_1v_2)$, a notation which we shall have occasion to recall hereafter. For illustration of Table, p. 23, see remarks at the end of next section.

Section 3.—This section opens with an expression for

$$\theta(u_1+v_1\,..\,u_\rho+v_\rho\tau_{1,1}\,..\,\tau_{\rho,\rho}), \quad \theta(u_1-pv_1\,..\,u_\rho-pv_\rho\,.\,.p\tau_{1,1}\,..\,p\tau_{\rho,\rho}),$$

where, it will be seen, a change of modulus is introduced. We proceed to prove the theorem, as it is enunciated without demonstration.

Recalling the value of (θ) given in Section 1, this expression is seen to be equivalent to $\Sigma\Sigma\epsilon^{F(u_1u_2)}$, where

$$\begin{aligned}&F(u_1u_2\,.\,)\\ &=(2\nu_1+2\sigma_1)u_1+(2\nu_1-2\sigma_1p)v_1+(\nu_1^2\ +ps_1^2)\tau_{1,1}\ \ +(\nu_1\nu_2+p\sigma_1\sigma_2)\tau_{1,2}+\,..\\ &+(2\nu_2+2\sigma_2)u_2+(2\nu_2-2\sigma_2p)v_2+(\nu_2\nu_1+p\sigma_2\sigma_1)\tau_{2,1}+(\nu_2^2\ +p\sigma_2^2)\tau_{2,2}\ \ +\,..\\ &+\&c.\\ &+(2\nu_\rho+2\sigma_\rho)u_\rho+(2\nu_\rho-2\sigma_\rho p)v_\rho+(\nu_\rho\nu_1+p\sigma_\rho\sigma_1)\tau_{\rho,1}+(\nu_\rho^2+p\sigma_\rho^2)\tau_{\rho,1}+\,..\end{aligned}$$

Now put

$$\begin{aligned}&\nu_1=s_1+n_1p+\mu_1, \quad \nu_2=s_2+n_2p+\mu_2, \quad \nu_3=s_3+n_3p+\mu_3\,...., \\ &\sigma_1=n_1-s_1, \quad \sigma_2=n_2-s_2, \quad \sigma_3=n_3-s_3\,....,\end{aligned}$$

which we may evidently do, provided that we sum with regard to $\mu_1, \mu_2\,..\,\mu_\rho$ from 0 to p.

Now we easily see that

$$\begin{aligned}\nu_1\nu_2+p\sigma_1\sigma_2&=\{\mu_1\mu_2\}+\{n_1p\mu_2+n_2p\mu_1+p(p+1)n_1n_2\}\\ &\quad+\{s_1\mu_2+s_2\mu_1+s_1s_2(p+1)\},\end{aligned}$$

the three brackets corresponding to the three factors in the following expression constituting the second member of the equation

$$\theta(u_1+v_1\,..)\theta(u_1-pv_1\,..)=\Sigma\{\epsilon^{\pi i\{\mu_1(\mu_1\tau_{1,1}+\,..)+\mu_2(\mu_1\tau_{2,1}+\,..)\}}\Sigma\epsilon^{P}\Sigma\epsilon^{Q}\},$$

where P=

$$\begin{aligned}&\{n_1\Big((2(p+1)u_1+\frac{2\mu_1u_1}{n_1}+2(\mu_1p\tau_{1,1}+\,..+\mu_\rho p\tau_{1,\rho})+p(p+1)(n_1\tau_{1,1}+n_2\tau_{1,2}+\,..)\Big)\\ &+n_2\Big(2(p+1)u_2+\frac{2\mu_2u_2}{n_2}+2(\mu p\tau_{2,1}+\,..+\mu p\tau_{2,\rho})+p(p+1)(n_2\tau_{2,1}+\,..)\Big)+\,....\}\pi i,\end{aligned}$$

$$Q=$$

$$\{s_1\left(2(p+1)v_1+\frac{2\mu_1 v_1}{s_1}+2(\mu\tau_{1,1}+\ldots\mu_\rho\tau_{1,\rho})+(p+1)(s_1\tau_{1,1}+s_2\tau_{1,2}+\ldots)\right)$$

$$+s_2\left(2(p+1)v_2+\frac{2\mu_2 v_2}{s_2}+2(\mu_1\tau_{2,1}+\ldots\mu_v\tau_{2,\rho})+(p+1)(s_1\tau_{2,1}+\ldots)\right)+\ldots\ldots\}\pi i,$$

from which Königsberger's formula may immediately be derived, where, however, the letter i must be exchanged in several places for the number 2, for which it is plainly intended.

Putting $p=1$, and multiplying the exponential partly into the function θ in u, and partly into the function θ in v, and recalling the definition of

$$\theta(v_1 v_2\ldots\ldots v_\rho,\quad nn_1n_2n_\rho)$$

given in the first section, we have at once

$$\theta(u_1+v_1\ldots u_\rho+v_\rho\tau_{1,1}\ldots\tau_{\rho,\rho})\theta(u_1-v_1\ldots u_\rho-v_\rho,\ \tau_{1,1}\ldots\tau_{\rho,\rho})$$
$$=\Sigma\theta(2u_1\ldots 2u_\rho,\ \tfrac{1}{2}\mu_1\ldots\tfrac{1}{2}\mu_{\rho,1},\ 2\tau_{1,1}\ldots 2\tau_{\rho,\rho})\theta(2v_1\ldots 2v_\rho,\ \tfrac{1}{2}\mu_1\ldots\tfrac{1}{2}\mu_\rho,\ 2\tau_{1,1}\ldots 2\tau_{\rho,\rho}).$$

A formula is next deduced for

$$\theta(u_1+v_1+w_1\ldots\ldots)\theta(u_1-v_1\ldots\ldots).$$

We have moreover

$$\theta(u_1+w_1\ldots\ldots u_\rho+w_\rho,\quad \tau_{1,1}\ldots\ldots\tau_{\rho,\rho})_\alpha\theta(u_1\ldots\ldots u_\rho\tau_{1,1}\ldots\ldots\tau_{\rho,\rho})_\alpha$$
$$=\Sigma\theta(2u_1+w_1\ldots\ldots 2u_\rho+w_\rho,\quad \tfrac{1}{2}\mu_1\ldots\ldots\tfrac{1}{2}\mu_\rho,\quad 2\tau_{1,1}\ldots\ldots\tau_{\rho,\rho})Q_\mu,$$

where Q_μ is not connected with u.

To prove this, we observe that, if we put $v_1=0$ in the last formulæ, we are able to show that

$$\theta(u_1\ldots\tau_{1,1}\ldots)_\alpha\theta(u_1+w_1\ldots\tau_{1,1}\ldots)$$
$$=\epsilon^{\Sigma\frac{n_v}{2}(2u_v+\frac{n_1}{2}\tau_{v,1}+\ldots+\frac{n_\rho}{2}\tau_{r,\rho})}\epsilon^{\Sigma\frac{n_v}{2}(2u_v+2w_v+\frac{n_1}{2}\tau_{r,1}+\ldots\ldots\frac{n_\rho}{2}\tau_{r,\rho})\pi i}$$

$$\Sigma\theta(2u_1+w_1+m_1^\alpha+n_1\tau_{1,1}+\ldots 2u_2+w_2+m_2^\alpha+n_1\tau_{2,1}\ldots\tfrac{1}{2}\mu_1\ldots\tfrac{1}{2}\mu_\rho\ldots 2\tau_{1,1}\ldots 2\tau_{\rho,\rho})P_\mu^{(1)}.$$

But

$$\theta(2u_1+w_1+m_1^\alpha+n_1\tau_{1,1}\ldots\tfrac{1}{2}\mu_1\ldots\tfrac{1}{2}\mu_\rho\ldots 2\tau_{1,1}\ldots 2\tau_{\rho,\rho})$$
$$=P_\mu^{(2)}\epsilon^{-\Sigma 2n_v u_v}\theta(2u_1+w_{1,1}2u_2+w_2\ldots\tfrac{1}{2}\mu_1\ldots\tfrac{1}{2}\mu_\rho 2\tau_{1,1}\ldots 2\tau_{\rho,\rho}).$$

Combining these two expressions together, we see that the theorem is true.

From this equation, by using 2^ρ values of (α) in succession, and eliminating, we may obtain each of the 2^ρ values of

$$\theta(2u_1+w_1\ldots\ldots 2u_\rho+w_\rho,\quad \tfrac{1}{2}\mu_1\ldots\ldots\tfrac{1}{2}\mu_\rho,\quad 2\tau_{1,1}\ldots\ldots 2\tau_{\rho,\rho})$$

corresponding to the 2^ρ values of $\mu_1\ldots\ldots\mu_\rho$ in terms of a series of functions of the form

$$\theta(u\ldots\ldots u_\rho,\quad \tau_{1,1}\ldots\ldots\tau_{\rho,\rho})_\alpha\theta(u+w_1\ldots\ldots u_\rho+w_\rho,\quad \tau_{1,1}\ldots\ldots\tau_{\rho,\rho})_\alpha,$$

whence the formula above mentioned for

$$\theta(u_1+v_1+w_1\ldots\ldots)\theta(u_1-v_1\ldots\ldots)$$

will become, by the substitution of these values,

$$\theta(u_1+v_1+w_1\ldots.u_\rho+v_\rho+w_\rho,\ \ \tau_{1,1}\ldots.\tau_{\rho,\rho})\theta(u_1-v_1\ldots.u_\rho-v_\rho,\ \ \tau_{1,1}\tau_{\rho,\rho})$$
$$=\sum_\alpha(\alpha)\theta(u_1\ldots.u_\rho,\ \ \tau_{1,1}\ldots.\tau_{\rho,\rho})_\alpha\theta(u_1+w_1\ldots.u_\rho+w_\rho,\ \ \tau_{1,1}\ldots.\tau_{\rho,\rho})_\alpha,$$

where the coefficients (α) are to be determined.

To determine these coefficients Konigsberger adopts a method from Weierstrass as follows.

Taking the ratio $\frac{\theta_1(v_1v_2\ldots.v_\rho)_\alpha}{\theta(v_1v_2\ldots.v_\rho)}$, and remembering its value as given in Weierstrass's paper (Crelle, xlvii.), or in the first section of the paper we are now considering, we see that it will be infinite when one of the quantities $x_1, x_2\ldots.x_\rho$ is infinite, and zero when they become equal to a_α.

From this Königsberger deduces the two equations corresponding to these conditions:—

$$\theta(v_1v_2\ldots.v_\rho)=0 \text{ to the first,}$$

and

$$\theta(v_1v_2\ldots.v_\rho)_\alpha=0 \text{ to the second,}$$

which last may be written

$$\theta(v_1+\tfrac{1}{2}m^1{}_1+\ldots.+\tfrac{1}{2}m_1^{2\rho-1}+\tfrac{1}{2}m_1^{\alpha_1}+\ldots\quad \tfrac{1}{2}m^{\alpha_r}\quad ,$$
$$v_\rho+\tfrac{1}{2}m^1{}_\rho+\ldots\ .+\tfrac{1}{2}m_\rho^{2\rho}\quad+\tfrac{1}{2}m_\rho^{\alpha_1}+\ldots.+\tfrac{1}{2}m_\rho^{\alpha_r},$$
$$\tfrac{1}{2}n'_1+\ldots.+\tfrac{1}{2}n_1^{2\rho-1}+\tfrac{1}{2}n_1^{\alpha_1}+\ldots.\quad \tfrac{1}{2}n_1^{\alpha_r}\ldots.)=0.$$

Königsberger then states that, if the symbol $(1.3.5\ldots.2\rho-1,\ \epsilon_1\epsilon_2\epsilon_\rho)$ is called ϵ', and δ being supposed to be any whole number, γ equal to every symbol of the form $\delta\epsilon$, and therefore taking 2^ρ forms, then $\theta(v_1v_2..v_\rho)_{\epsilon'\gamma'\gamma''}=0$, when $v_1v_2\ldots.v_\rho$ vanish, γ' and γ'' being different. To show this we remark that the increments of the arguments $v_1v_2\ldots.v_\rho$ are partly numerical, partly consist of definite integrals. When γ' and γ'' are different, the numerical part becomes entire; and therefore when $v_1v_2\ldots.v_\rho$ vanish, θ vanishes by a proposition of Weierstrass for the expansion of θ, when the arguments are increased by semiperiods of definite integrals. (See Crelle, xlvii. p. 30.) When γ' and γ'' are the same, they counteract each other and produce no effect. From these considerations Konigsberger deduces the values of the coefficients (α)*.

I shall illustrate the Table, p. 28, by deducing from the last equation of p. 27:—

$$\theta_4\theta_{1,4}P_1Q_5=p_5p_1q_4q_{1,4}+p_0p_{0,1}q_{0,4}q_{2,3}-p_2p_{1,2}q_{2,4}q_{0,3}-p_{0,2}p_{3,4}q_{1,3}q_3.$$

Put $w_1=-v_1$ in the equation mentioned, $\epsilon'=4, \alpha=1, \beta=5, \theta(v_1+w_1\ldots.)_{\epsilon',\alpha,\beta}$ becomes $\theta(v_1v\ldots.)_{1,4,5}=\theta_{1,4}$ (see remark at the end of our remarks on section 2). Since we are dealing with hyperelliptic functions of the first order, ϵ_1 and ϵ_2 will become 0 and 2; hence γ becomes in succession in the four terms of the formula, 5, 0, 2, 02, $\gamma\alpha\beta$ (omitting $\beta=5$ and $\gamma=5$), 1, 01, 12, 012, or 1, 01, 12, 34, as we shall see, $\alpha\epsilon'\gamma$ becomes 145, 140, 142, 1402, or 14, 23, 03, 3; $\beta\epsilon'\gamma$ becomes 545, 540, 542, 5402, or 4, 04, 24, 13, which give the indices required.

* Königsberger has been very brief in this paragraph from Weierstrass. I am not sure of his meaning. I hope to add something in the Supplement.

To make this more clear I add the following proofs of some of these equivalences (see Table, p. 22):—

$$\theta(u_1u_2)_{012}=\theta(v_1-\tfrac{1}{2}-\tfrac{1}{2},\ v_2-\tfrac{1}{2},\ 0,\ 0)=\theta(v_{1,1}v_2-\tfrac{1}{2},\ 0,\ 0)=\theta(v_1v_2)_{34},$$

$$(\theta u_1u_2)_{1402}=\theta(v_1-\tfrac{1}{2}-\tfrac{1}{2},\ v_2-\tfrac{1}{2},\ \tfrac{1}{2}+\tfrac{1}{2},\ \tfrac{1}{2}+0)=\theta(v_1,\ v_2-\tfrac{1}{2},\ 0,\ \tfrac{1}{2})=\theta(v_1v_2)_3.$$

The other formulæ in the Table may be proved in a similar manner.

Section 4.—Königsberger in this section gives the following theorem (without demonstration):—

If

$$\phi(u_1\ldots u_\rho)=\theta(m_1^{(1)}u_1+a_{1,1}^{(1)}\ldots m_1^{(1)}u_\rho+a_\rho^{(1)},\quad s_1^{(1)}\ldots s_\rho^{(1)})$$
$$\ldots\theta(m_1^\lambda u_1+a_1^\lambda\ldots m_1^\lambda u_\rho+a_\rho^\lambda,\quad s_1^{(\lambda)}\ldots s_\rho^{(\lambda)}),$$

then

$$\Sigma\epsilon^{-\Sigma_\nu\frac{S_\nu}{r}\{2ru_\nu+2u_\nu-(S_1\tau_{\nu,1}+\ldots+S_\rho\tau_{\nu,\rho})\}\pi i}$$

$$\times\phi\left(u_1+\frac{n_1}{r_1}-\frac{1}{r}(A_1+S_1\tau_{1,1}+\ldots+S_\rho\tau_{1,\rho})\ldots u_\rho+\frac{n_\rho}{r_\rho}-\frac{1}{r}(A_\rho+S_1\tau_{\rho,1}+\ldots S_\rho\tau_{\rho,\rho})\right)$$
$$=C\theta(ru_1\ldots ru_\rho,\quad r\tau_{1,1}\ldots r\tau_{\rho,\rho}),$$

where the summation with regard to the indices $n_1\ldots n_\rho$ extends from 0 to $r-1$, and r, A, S are given by the following equations:—

$$\begin{aligned} m_1^{(1)2} &+ \ldots + m_1^{(\lambda)2} &&= r,\\ m_1^{(1)}a_\nu^{(1)} &\ \ \ldots + m_1^{(\lambda)}a_\nu^{(\lambda)} &&= A_\nu,\\ m_1^{(1)}s_\nu^{(1)} &+ \ldots + m_1^{(\lambda)}s_\nu^{(\lambda)} &&= S_\nu. \end{aligned}$$

I have worked out this theorem for hyperelliptic functions of the first order; and it appears from this that the demonstration for hyperelliptic functions does not differ in principle from that for elliptic functions. I shall therefore confine myself to elliptic functions, as the length for hyperelliptic functions is extremely great.

Putting then $\rho=1$, the theorem becomes

$$\Sigma\epsilon^{-\frac{S_1}{r}(2ru+2n-S_1\tau_{1,1})\pi i}\phi(u+\frac{n}{r}-\frac{1}{r}(A_1+S_1\tau_{1,1}))=C\theta(ru_{1,1}r\tau_{1,1}).$$

For $\lambda=1$, this equation reduces itself to the following—

$$\Sigma\epsilon^{-\frac{s}{m}(2m^2u+2n-ms\tau_{1,1})\pi i}\theta(mu+\frac{n}{m}-(a+s\tau_{1,1})+a:s))=C\theta(m^2u_1,m^2\tau_{1,1}),$$

or

$$\theta\left(mu+\frac{n}{m}\right)=C\theta(m^2u_1,\ m^2\tau_{1,1}),$$

which leads at once to the equivalence

$$\Sigma_n\Sigma_\nu\epsilon^{\nu(2mu+\frac{2n}{m}+\nu\tau_{1,1})\pi i}=C\Sigma\epsilon^{\nu(2m^2u+\nu m^2\tau_{1,1})\pi i}.$$

Put in this equation $\nu=\nu'm+\mu$, where μ is less than m. Then we have

$$\Sigma_n\Sigma_\nu\epsilon^{\nu(2mu+\frac{2n}{m}+\nu\tau_{1,1})\pi i}=\sum_n\sum_{\nu'}\sum_\mu\epsilon^{\frac{2n\pi i}{m}(\nu'm+\mu)}\cdot\epsilon^{(\nu'm+\mu)\pi i(2mu+(\nu'm+\mu)\tau_{1,1})},$$

(remembering that $\sum\limits_{n} \epsilon^{\frac{2n\pi i}{m}(\nu' m+\mu)}$ vanishes, except when $\mu=0$, when it becomes unity)

$$=\sum_{\nu} \epsilon^{\nu'(2m^2u+\nu' m^2\tau_{1,1})},$$

which is what we want to prove.

Taking now the general case for elliptic functions, we have

$$\phi(u)=\theta(m'u+a' : s^{(1)})\theta(m^{(2)}u+a^{(2)} : s^{(2)})\ldots.\theta(m^{\lambda}u+u^{\lambda} : s^{\lambda})$$

and

$$\phi\left(u+\frac{n}{r}-\frac{1}{r}(\mathrm{A}_1+\mathrm{S}_1\tau_{1,1})\right)$$

$$=\phi\left(u+\frac{n}{r}-\frac{1}{r}(m^{(1)}a^{(1)}+m^{(2)}a^{(2)}+\ldots.m^{\lambda}a^{\lambda})-\frac{\tau_{1,1}}{r}(m^{(1)}s^{(1)}+\ldots.m^{\lambda}s^{\lambda})\right).$$

It is easy to develop this expression by means of the principles already laid down; and we have, finally,

$$\sum_{n}\epsilon^{-\frac{\mathrm{S}_1}{r}(2\nu u+2n-\mathrm{S}_1\tau_{1,1})\pi i}\phi\left(u+\frac{n}{r}-\frac{1}{r}(\mathrm{A}_1+\mathrm{S}_1\tau_{1,1})\right)$$

$$=\sum\epsilon^{-\frac{m^{(1)}s^{(1)}+m^{(2)}s^{(2)}+\ldots+m^{(\lambda)}s^{(\lambda)}}{r}\{2ru+2n-(m^{(1)}s^{(1)}+m^{(2)}s^{(2)}+\ldots+m^{(\lambda)}s^{(\lambda)})\tau_{1,1}\}\pi i}$$

$$\epsilon^{s_1\left(2m^{(1)}u+\frac{2m^{(1)}n}{r}-\frac{2m^{(1)}}{r}(m^{(1)}a^{(1)}+\ldots+m^{\lambda}a^{\lambda})-\frac{2m^{(1)}\tau_{1,1}}{r}(m^{(1)}s^{(1)}+\ldots m^{\lambda}s^{\lambda})+2a^{(1)}+s_1\tau_{1,1}\right)\pi i}$$

$$\sum_{\nu_1}\epsilon^{\nu_1\left(2m^{(1)}u+\frac{2m^{(1)}n}{r}-\frac{2m^{(1)}}{r}(m^{(1)}a^{(1)}\ldots m^{\lambda}a^{\lambda})-\frac{2m^{(1)}\tau_{1,1}}{r}(m^{(1)}s^{(1)}+\ldots m^{(\lambda)}s^{\lambda})+2a'+2s_1\tau_{1,1}+\nu'''\tau_{1,1}\right)\pi i}$$

$$\sum^{s_2}\left(2m_2u+\frac{2m^{(2)}n}{r}-\frac{2m^{(2)}}{r}(m^{(1)}a^{(1)}+\ldots+m^{\lambda}a^{\lambda})-\frac{2m^2\tau_{1,1}}{r}(m^{(1)}s^{(1)}+\ldots+m^{\lambda}s^{\lambda})+2a_2+s_2\tau_{1,1}\right)\pi i$$

$$\sum_{\nu_2}\epsilon^{\nu_2\left(2m^{(2)}u+\frac{2m^{(2)}n}{r}-\frac{2m^{(2)}}{r}(m^{(1)}a^{(1)}+\ldots+m^{\lambda}a^{\lambda})-\frac{2m^{(2)}\tau_{1,1}}{r}(m^{(1)}s^{(1)}+\ldots+m^{\lambda}s^{\lambda})+2a^{(2)}+2s^{(2)}\tau_{1,1}+\nu^{(2)}\tau_{1,1}\right)\pi i}$$

$$\times\ldots\ldots\ldots$$

Putting in this expression $\nu_1=m^{(1)}\nu+\mu^{(1)}$, $\nu^{(2)}=m^{(2)}\nu+\mu^{(2)}$, $\nu^{(3)}=m^{(3)}\nu+\mu^{(3)}$, where $\mu^{(1)}$ is less than $m^{(1)}\ldots.$, we see that the expression vanishes, except when $\mu^{(1)}=0$, $\mu^{(2)}=0\ldots.$, and that consequently the expression takes the form $\mathrm{C}\theta(ru, r\tau_{1,1})$. Another theorem for $\phi(u_1u_2\ldots. u\ )$ is given by Königsberger in this section.

Section 5.—Königsberger here gives two series of hyperelliptic functions, and proposes to determine the coefficients of the second series in such a way that they may be expressed rationally by means of the first. It follows as a consequence that the periods of one set of these functions can be expressed linearly in terms of the periods of the other, the coefficients in these linear relations, however, being subject to the condition

$$\Sigma(\mathrm{K}_{\nu,c}\mathrm{K}'_{\mu,c'}-\mathrm{K}_{\nu,c}\mathrm{K}'_{\mu,c'})=0.$$

Section 6.—Königsberger then proceeds more immediately to the transformation of functions θ, the expression of

$$\theta(nu_1\ldots. nu_\rho n_{1,1}\ldots. n\tau_{\rho,\rho}) \text{ by } \theta(u_1\ldots. u_{\rho,\rho}\tau_{1,1}\ldots. \tau_{\rho,\rho})a.$$

In the theorem of last section, let

$$\phi(u_1u_2 \ldots u_s)=\theta(u_1u_2 \ldots u_\rho)\theta\left(u_1+\frac{1}{n} \ldots u_\rho+\frac{1}{n}\right) \ldots \theta\left(u_1+\frac{n-1}{n} \ldots u_\rho+\frac{n-1}{n}\right);$$

this is equivalent to assuming $s=0$, $m=1$, $\lambda=n$,

$$a_1^1=a_2^1=\ldots a_\rho^1=0,$$

$$a_1^2=a_2^{(2)}=\ldots a_\rho^{(2)}=\frac{1}{n},$$

$$\ldots$$

$$a_1^\lambda=a_2^\lambda=\ldots a_\rho^\lambda=\frac{n-1}{n}.$$

Hence $$A_1=A_2=\ldots\frac{n-1}{2},$$

and the theorem becomes

$$\Sigma\phi\left(u_1+\frac{n_1}{n}-\frac{n-1}{2n} \ldots u_\rho+\frac{n_\rho}{n}-\frac{n-1}{2n}\right)=C\theta(nu_1 \ldots nu_\rho,\ n\tau_{1,1} \ldots \tau_2\tau_{\rho,\rho}).$$

We shall apply this to prove the theorem for the transformation of the Abelian integrals of the first order given on page 32.

Put $n=3$, $\rho=2$; take n_1n_2 successively 0, 1, 2.

Then
$$\begin{aligned}
\Sigma\phi=\ &\phi(u_1-\tfrac{1}{3},\ u_2-\tfrac{1}{3})+\phi(u_1u_2-\tfrac{1}{3})+\phi(u_1+\tfrac{1}{3},\ u_2-\tfrac{1}{3}),\\
&+\phi(u_1-\tfrac{1}{3},\ u_2)+\phi(u_1u_2)+\phi(u_1+\tfrac{1}{3},\ u_2),\\
&+\phi(u_1-\tfrac{1}{3},\ u_2+\tfrac{1}{3})+\phi(u_1,\ u_2+\tfrac{1}{3})+\phi(u_1+\tfrac{1}{3},\ u_2+\tfrac{1}{3}).\\
=\ &\theta(u_1-\tfrac{1}{3},\ u_2-\tfrac{1}{3})\theta(u_1u_2)\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{1}{3}) \quad \ldots \quad (1)\\
&+\theta(u_1u_2-\tfrac{1}{3})\theta(u_1+\tfrac{1}{3},\ u_2)\theta(u_1+\tfrac{2}{3},\ u_2+\tfrac{1}{3}) \quad \ldots \quad (2)\\
&+\theta(u_1+\tfrac{1}{3},\ u_2-\tfrac{1}{3})\theta(u_1+\tfrac{2}{3},\ u_2)\theta(u_1+\tfrac{3}{3},\ u_2+\tfrac{1}{3}) \quad \ldots \quad (3)\\
&+\theta(u_1-\tfrac{1}{3},\ u_2)\theta(u_1,\ u_2+\tfrac{1}{3})\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{2}{3}) \quad \ldots \quad (4)\\
&+\theta(u_1u_2)\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{1}{3})\theta(u_1+\tfrac{2}{3},\ u_2+\tfrac{2}{3}) \quad \ldots \quad (5)\\
&+\theta(u_1+\tfrac{1}{3},\ u_2)\theta(u_1+\tfrac{2}{3},\ u_2+\tfrac{1}{3})\theta(u_1+\tfrac{3}{3},\ u_2+\tfrac{2}{3}) \quad \ldots \quad (6)\\
&+\theta(u_1-\tfrac{1}{3},\ u_2+\tfrac{1}{3})\theta(u_1,\ u_2+\tfrac{2}{3})\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{3}{3}). \quad \ldots \quad (7)\\
&+\theta(u_1,\ u_2+\tfrac{1}{3})\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{2}{3})\theta(u_1+\tfrac{2}{3},\ u_2+\tfrac{3}{3}) \quad \ldots \quad (8)\\
&+\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{1}{3})\theta(u_1+\tfrac{2}{3},\ u_2+\tfrac{2}{3})\theta(u_1+\tfrac{3}{3},\ u_2+\tfrac{3}{3}). \quad \ldots \quad (9)
\end{aligned}$$

We see that lines (159), (267), (348) are identical; and the theorem of last section therefore becomes

$$\begin{aligned}
&\theta(u_1u_2)\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{1}{3})\theta(u_1+\tfrac{2}{3},\ u_2+\tfrac{2}{3})\\
&+\theta(u_1+\tfrac{1}{3},\ u_2)\theta(u_1+\tfrac{2}{3},\ u_2+\tfrac{1}{3})\theta(u_1u_2+\tfrac{2}{3})\\
&\theta(u_1u_2+\tfrac{1}{3})\theta(u_1+\tfrac{1}{3},\ u_2+\tfrac{2}{3})\theta(u_1+\tfrac{2}{3},\ u_2)\\
&=C\theta(3u_1,\ 3u_2,\ 3\tau_{1,1},\ 3\tau_{1,2},\ 3\tau_{2,2}).
\end{aligned}$$

To illustrate the series of equations next following, I observe:—

$$\begin{aligned}&\theta(v_1 \ldots . v_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_{3,4}\\&=\theta(v_1-0-0,\ v_2-\tfrac{1}{2}-0,\ v_3-\tfrac{1}{2}-\tfrac{1}{2},\ \ldots .)\\&=\theta(v_1,\ v_2-\tfrac{1}{2},\ v_3 \ldots .).\end{aligned}$$

Hence, substituting $v_2-\frac{1}{2}$ in the value of $\theta(2v_1 \ldots . 2v_\rho,\ \frac{1}{2}\mu_1 \ldots . \frac{1}{2}\mu_\rho,\ 4\tau_{1,1} \ldots . 4\tau_{\rho,\rho})$ just given, the expression becomes

$$\Sigma(-1)^{\mu_2}\theta(2v_1 \ldots . 2v_\rho,\ \tfrac{1}{2}\mu_1 \ldots . \tfrac{1}{2}\mu_\rho,\ 4\tau_{1,1} \ldots 4\tau_{\rho,\rho}). \quad . \quad . \quad . \quad \text{(A)}$$

From this series of equations values are deduced for

$$\theta(2v_1 \ldots 4\tau_{1,1} \ . \ .) \text{ and } \theta(2v_1 \ldots . \tfrac{1}{2}\mu_1 \ldots . 4\tau_{1,1})$$

in terms of

$$\theta(v_1 \ldots \tau_{1,1} \ldots .)_\alpha.$$

Putting $p=3$ in the theorem at the commencement of section 3, and then for u_1, $u_1-\frac{1}{2}$, &c., an expression is found for

$$\sum_\alpha \theta(u_1+v_1 \ldots . u_\rho+v_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha \theta(u_1-3v_1 \ldots . 3\tau_{1,1} \ldots .)_\alpha.$$

Modifying this by the equation for $\theta(2v_1 \ . \frac{1}{\mu_1} . . 4\tau_{1,1})$, which we have just mentioned, we have

$$\begin{aligned}&\sum_\alpha \theta(u_1+v_1 \ldots . u_\rho v_\rho\,;\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha (u_1-3v_1 \ldots . 3\tau_{1,1} \ldots .)_\alpha\\&=\frac{1}{2^\rho}\sum_\mu\{\sum_\gamma(-1)^{\Sigma_\nu \mu_\nu m_\nu^\gamma}\theta(2u_1 \ldots . 2u_\rho\,;\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_\gamma,\\&\qquad \sum_\delta(-1)^{\Sigma\mu_\tau m_\nu^\delta}\theta(2v_1 \ldots . 2v_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\delta\}.\end{aligned}$$

Now we observe here that the index of (-1) in both cases is a series of negative units, *every one* of which is multiplied by a quantity which is 0 and 1 alternately. Hence, in taking the sum, the expression vanishes except for $\gamma=\delta$, and we have, when $v_1=v_2=\ldots .=v_\rho=0$,

$$\begin{aligned}&\sum_\alpha \theta(u_1 \ldots . u_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha \theta(u_1 \ldots . u_\rho,\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_\alpha\\&=\sum_\alpha \theta(2u_1 \ldots . 2u_\rho\,;\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_\alpha \theta(0 \ldots . 0,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha.\end{aligned}$$

From this we easily obtain, bearing in mind the method by which expression (A) was found,

$$\begin{aligned}&\sum_\alpha \theta(0 \ldots . 0,\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_{\alpha,\mu}\theta(0 \ldots . 0,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_{\alpha,\mu}\\&=\sum_\alpha(-1)^{\Sigma_\nu n_\nu^\mu m_\nu^\mu}\theta(0 \ldots . 0,\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_\alpha \theta(0 \ldots . 0,\ \tau_{1,1}\tau \ldots . \tau_{\rho,\rho})_\alpha.\end{aligned}$$

From this formula Königsberger deduces three modular equations for hyperelliptic functions of the first order. Since $3\rho-3$ is in this case 3, and as this number is taken with one exception, the number of terms in the first member of these equations is 2, the four terms in the second member correspond to the values v_1, v_2; $v_1-\frac{1}{2}, v_2$; $v_1, v_2-\frac{1}{2}$; $v_1-\frac{1}{2}, v_2-\frac{1}{2}$.

To illustrate the series of equations next following, I observe :—

$$\begin{aligned}&\theta(v_1 \ldots . v_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_{3,4}\\ &=\theta(v_1-0-0,\ v_2-\tfrac{1}{2}-0,\ v_3-\tfrac{1}{2}-\tfrac{1}{2},\ \ldots .)\\ &=\theta(v_1,\ v_2-\tfrac{1}{2},\ v_3 \ldots .).\end{aligned}$$

Hence, substituting $v_2-\frac{1}{2}$ in the value of $\theta(2v_1 \ldots . 2v_\rho,\ \frac{1}{2}\mu_1 \ldots . \frac{1}{2}\mu_\rho,\ 4\tau_{1,1} \ldots . 4\tau_{\rho,\rho})$ just given, the expression becomes

$$\Sigma(-1)^{\mu_2}\theta(2v_1 \ldots . 2v_\rho,\ \tfrac{1}{2}\mu_1 \ldots . \tfrac{1}{2}\mu_\rho,\ 4\tau_{1,1} \ldots 4\tau_{\rho,\rho}). \quad . \quad . \quad . \quad \text{(A)}$$

From this series of equations values are deduced for

$$\theta(2v_1 \ldots 4\tau_{1,1} \ldots) \text{ and } \theta(2v_1 \ldots . \tfrac{1}{2}\mu_1 \ldots . 4\tau_{1,1})$$

in terms of

$$\theta(v_1 \ . \ . \tau_{1,1} \ldots)_\alpha.$$

Putting $p=3$ in the theorem at the commencement of section 3, and then for u_1, $u_1-\frac{1}{2}$, &c., an expression is found for

$$\sum_\alpha \theta(u_1+v_1 \ldots . u_\rho+v_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha \theta(u_1-3v_1 \ldots . 3\tau_{1,1} \ldots .)_\alpha.$$

Modifying this by the equation for $\theta(2v_1 \ . \ \frac{1}{\mu_1} . . 4\tau_{1,1})$, which we have just mentioned, we have

$$\begin{aligned}&\sum_\alpha \theta(u_1+v_1 \ldots u_\rho v_\rho\ ;\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha (u_1-3v_1 \ldots . 3\tau_{1,1} \ldots .)_\alpha\\ &=\frac{1}{2^\rho}\sum_\mu \{\sum_\gamma(-1)^{\Sigma\mu_\nu m^\gamma_\nu}\theta(2u_1 \ldots . 2u_\rho\ ;\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_\gamma,\\ &\qquad \sum_\delta(-1)^{\Sigma\mu_\tau m^\delta_\nu}\theta(2v_1 \ldots . 2v_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\delta\}.\end{aligned}$$

Now we observe here that the index of (-1) in both cases is a series of negative units, *every one* of which is multiplied by a quantity which is 0 and 1 alternately. Hence, in taking the sum, the expression vanishes except for $\gamma=\delta$, and we have, when $v_1=v_2= \ldots =v_\rho=0$,

$$\begin{aligned}&\sum_\alpha \theta(u_1 \ldots . u_\rho,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha \theta(u_1 \ldots . u_\rho,\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_\alpha\\ &=\sum_\alpha \theta(2u_1 \ldots . 2u_\rho\ ;\ 3\tau_{1,1} \ . \ . 3\tau_{\rho,\rho})_\alpha \theta(0 \ldots . 0,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_\alpha.\end{aligned}$$

From this we easily obtain, bearing in mind the method by which expression (A) was found,

$$\begin{aligned}&\sum_\alpha \theta(0 \ldots . 0,\ 3\tau_{1,1} \ldots 3\tau_{\rho,\rho})_{\alpha,\mu}\theta(0 \ldots . 0,\ \tau_{1,1} \ldots . \tau_{\rho,\rho})_{\alpha,\mu}\\ &=\sum_\alpha(-1)^{\Sigma n^\mu_\nu m^\mu_\nu}\theta(0 \ldots . 0,\ 3\tau_{1,1} \ldots . 3\tau_{\rho,\rho})_\alpha \theta(0 \ldots . 0,\ \tau_{1,1}\tau \ldots . \tau_{\rho,\rho})_\alpha.\end{aligned}$$

From this formula Königsberger deduces three modular equations for hyperelliptic functions of the first order. Since $3\rho-3$ is in this case 3, and as this number is taken with one exception, the number of terms in the first member of these equations is 2, the four terms in the second member correspond to the values v_1, v_2; $v_1-\frac{1}{2}, v_2$; $v_1, v_2-\frac{1}{2}$; $v_1-\frac{1}{2}, v_2-\frac{1}{2}$.

Section 8.—This section is very short, and contains some formulæ for transformation when the moduli are doubled.

From the equation

$$\theta(u_1+v_1\ldots\ldots u_\rho+v_\rho,\ \tau_{1,1}\ldots\ldots\tau_{\rho,\rho})\theta(u_1-v_1\ldots\ldots u_\rho-v_\rho,\ \tau_{1,1}\ldots\ldots\tau_{\rho,\rho})=$$

$$\sum_\mu(2u_1\ldots\ldots 2u_\rho,\ \frac{\mu_1}{2}\ldots\ldots\frac{\mu_\rho}{2},\ 2\tau_{1,1}\ldots\ldots 2\tau_{\rho,\rho})\theta(2v_1\ldots\ldots,\ \frac{\mu_1}{2}\ \ldots\ldots\ 2\tau_{1,1}\ldots\ \ )$$

is deduced by means similar to those used in the last section,

$$\theta(2u_1\ldots\ldots 2u_\rho,\ 2\tau_{1,1}\ldots\ldots 2\tau_{\rho,\rho})\theta(2v_1\ldots\ldots 2v_\rho,\ 2\tau_{1,1}\ldots\ldots 2\tau_{\rho,\rho})$$

$$=\frac{1}{2^\rho}\sum_a\theta(u_1+v_1\ldots\ldots u_\rho+v_\rho,\ \tau_{1,1}\ldots\ldots\tau_{\rho,\rho})_a\theta(u_1-v_1\ldots\ldots\tau_{1,1}\ldots\ldots)_a;$$

and from this equation one or two other expressions are derived.

In section 9 the application of these principles is made on a more extended scale to hyperelliptic functions of the first order; as, however, this is presented in a more developed state in the sixty-fifth volume of Crelle's Journal, we proceed at once to the second memoir, and shall follow, as before, Konigsberger's division as to sections.

Section 1.—We now recur to the equations at the beginning of Konigsberger's first paper. Putting $\rho=2$, we have

$$u_1=2K_{1,1}v+2K_{1,2}v_2,\quad v_1=G_{1,1}u_1+G_{2,1}u_2,$$

$$u_2=2K_{2,1}v+2K_{2,2}v_2,\quad v_2=G_{1,2}u_1+G_{2,2}u_2,$$

$$\tau'_{1,1}=2iG_{1,1}K'_{1,1}+2iG_{2,1}K'_{2,1},$$

whence

$$G_{1,1}=\frac{K_{2,2}}{2(K_{1,1}K_{2,2}-K_{2,1}K_{1,2})},\quad G_{2,1}=\frac{K_{2,1}}{2(K_{1,2}K_{2,1}-K_{2,2}K_{1,1})};$$

whence

$$\tau'_{1,1}=\frac{i(K_{2,2}K'_{1,1}-K_{2,1}K'_{2,1})}{K_{1,1}K_{2,2}-K_{2,1}K_{1,2}},$$

with similar values for $\tau'_{1,2}$, $\tau'_{2,1}$, $\tau'_{2,2}$.

The following notation is adopted in Konigsberger's second paper:

$$R\,(x)=x(1-x)(1-\kappa^2x)(1-l^2x)(1-m^2x),$$

$$R_1(y)=y(1-y)(1-k^2y)(1-\lambda^2y)(1-\mu^2y),$$

$$\frac{dy}{\sqrt{R_1y_1}}+\frac{dy_2}{\sqrt{R_1y_2}}=du_1,\quad \frac{y_1dy_1}{\sqrt{R_1y_1}}+\frac{y_2dy_2}{\sqrt{R_1y_2}}=du_2,$$

$$\frac{dx_1}{\sqrt{Rx_1}}+\frac{dx_2}{\sqrt{Rx_2}}=du'_1=\alpha du_1+\beta du_2,$$

$$\frac{x_1dx_1}{\sqrt{Rx_1}}+\frac{x_2dx_2}{\sqrt{Rx_2}}=du'_2=\gamma du_1+\delta u_2.$$

These equations are plainly connected together; and, the usual notation of Dr. Weierstrass being used, we have

$$\frac{\sqrt{\left(\frac{1}{\lambda^2}-y_1\right)\left(\frac{1}{\lambda^2}-y_2\right)}}{\sqrt[4]{\frac{-R'_1\frac{1}{\lambda^2}}{\kappa^2\lambda^2\mu^2}}}=\frac{\theta(v'_1, v'_2, \tau'_{1,1}, \tau'_{1,2}, \tau'_{2,2})_1}{\theta(v'_1, v'_2, \tau'_{1,1}, \tau'_{1,2}, \tau'_{2,2})_5}=al(u_1u_2, \kappa_1\lambda_1\mu_1)_1,$$

$$\frac{\sqrt{-(1-y_1)(1-y_2)}}{\sqrt[4]{\frac{-R'_1(1)}{\kappa^2\lambda^2\mu^2}}}=\frac{\theta(v'_1, v'_2, \tau'_{1,1}, \tau'_{1,2}, \tau'_{2,2})_3}{\theta(v'_1, v'_2, \tau'_{1,1}, \tau'_{1,2}, \tau'_{2,2})_5}=al(u_1u_2\kappa\lambda\mu)_3,$$

where

$$u_1=2K_{1,1}v'_1+2K_{1,2}v'_{2,1}u_2=2K_{2,1}v'_1+2K_{2,2}v'_2,$$

and $\tau'_{1,1}$ &c. have the values we have just given,

$$\frac{\sqrt{\left(\frac{1}{l^2}-x_1\right)\left(\frac{1}{l^2}-x_2\right)}}{\sqrt[4]{\frac{-R'\frac{1}{l^2}}{c^2l^2m^2}}}=\frac{\theta(v_1, v_2, \tau_{1,1}, \tau_{1,2}, \tau_{2,2})_1}{\theta(v_1, v_2, \tau_{1,1}, \tau_{1,2}, \tau_{2,2})_5}$$

$$=al(\alpha u_1+\beta u_2+\epsilon,\ \ \gamma u_1+\delta u_2+\zeta,\ c,\ l,\ m)_1.$$

$$\frac{\sqrt{-(1-x_1)(1-x_2)}}{\sqrt[4]{\frac{-R'(1)}{c^2l^2m^2}}}=\frac{\theta(v_1, v_2, \tau_{1,1}, \tau_{1,2}, \tau_{2,2})_3}{\theta(v_1, v_2, \tau_{1,1}, \tau_{1,2}, \tau_{2,2})_5}$$

$$=al(\alpha u_1+\beta u_2+\epsilon,\ \ \gamma u_1+\delta u_2+\zeta,\ c,\ l,\ m)_3,$$

where ϵ and ζ are two constants introduced by the integration.

Also

$$\alpha u_1+\beta u_2+\epsilon=2C_{1,1}v_1+2C_{1,2}v_2,$$

$$\gamma u\ +\delta u_2+\zeta=2C_{2,1}v_1+2C_{2,2}v_2,$$

where the quantities C are the same definite integrals as the quantities K, if c, l, m are substituted for κ, λ, μ, and τ has the same relation to C that τ' has to K.

After giving a variety of formulæ about the periods of the hyperelliptic functions, in conformity with the notation adopted by Dr. Weierstrass, Königsberger states the problem of transformation thus:—

If

$$\alpha u_1+\beta u_2+2\alpha mK_{1,1}+2\beta mK_{2,1}+\epsilon=2C_{1,1}w'_1+2C_{1,2}w'_2,$$

$$\gamma u_1+\delta u_2+2\gamma mK_{1,1}+2\delta mK_{2,1}+\zeta=2C_{2,1}w'_1+2C_{2,2}w'_2,$$

and

$$\alpha u_1+\beta u_2+2\alpha nK_{1,1}+2\beta nK_{2,1}+\epsilon=2C_{1,1}w_1+2C_{1,2}w_2,$$

$$\gamma u_1+\delta u_2+2\gamma nK_{1,1}+2\delta nK_{2,1}+\zeta=2C_{2,1}w_1+2C_{2,2}w_2,$$

corresponding to the periodic system

$$al(u_1+2K_{1,1},\ \ u_2+2K_{2,1})^2_\alpha=al^2(u_1u_2)_\alpha,$$

to express $w'_1 w'_2$ in terms of $w_1 w_2$, so that

$$\frac{\theta(w'_1, w'_2)_1^2}{\theta(w'_1, w'_2)_5^2} = \frac{\theta(w_1, w_2)_1^2}{\theta(w_1, w_2)_5^2}, \quad \frac{\theta(w'_1, w'_2)_3^2}{\theta(w'_1, w'_2)_5^2} = \frac{\theta(w_1, w_2)_3^2}{\theta(w_1, w_2)_5^2},$$

and also

$$\frac{\theta(w'_1, w'_2)_{1,3}^2}{\theta(w'_1, w'_2)_5^2} = \frac{\theta(w_1, w_2)_{1,3}^2}{\theta(w_1, w_2)_5^2}.$$

Section 2.—For the purpose of solving these equations, a Table similar to that we have endeavoured to explain at the end of our remarks on section 3 of Königsberger's first memoir is constructed; using the same notation, we have

$$\begin{aligned} \theta_5^2 P_1 Q_1 &= -p_5^2 q_1^2 + p_1^2 q_5^2 - p_3^2 q_{1,3}^2 + p_{1,3}^2 q_3^2, \\ \theta_5^2 P_3 Q_3 &= -p_5^2 q_3^2 + p_1^2 q_{1,3}^2 + p_3^2 q_5^2 - p_{1,3}^2 q_1^2, \\ \theta_5^2 P_{1,3} Q_{1,3} &= -p_5^2 q_{1,3}^2 - p_1^2 q_3^2 + p_3^2 q_1^2 + p_{1,3}^2 q_5^2. \end{aligned}$$

These three equations, combined with the last three equations of section 1, manifestly give the following:

$$\begin{aligned} \theta(w'_1 + w_1, \ w'_2 + w_2)_1 \ \theta(w'_1 - w_1, \ w'_2 - w_2)_1 &= 0, \\ \theta(w'_1 + w_1, \ w'_2 + w_2)_3 \ \theta(w'_1 - w_1, \ w'_2 - w_2)_3 &= 0, \\ \theta(w'_1 + w_1, \ w'_2 + w_2)_{1,3} \theta(w'_1 - w_1, \ w'_2 - w_2)_{1,3} &= 0, \end{aligned}$$

which reduces the problem to the solution of

$$\begin{aligned} \theta(w'_1 - w_1, \ w'_2 - w_2)_1 &= 0, \\ \theta(w'_1 - w_1, \ w'_2 - w_2)_3 &= 0, \\ \theta(w'_1 - w_1, \ w'_2 - w_2)_{1,3} &= 0. \end{aligned}$$

To resolve these equations Königsberger enunciates the following properties:—

If $e_1 e_2$ are quantities which satisfy the three equations

$$\theta(e_1 e_2)_1 = 0, \quad \theta(e_1 e_2)_3 = 0, \quad \theta(e_1 e_2)_{1,3} = 0,$$

then also the three following equations are true:—

$$\frac{\theta(u_1 + e_1, u_2 + e_2)_1^2}{\theta(u_1 + e_1, u_2 + e_2)_5^2} = \frac{\theta(u_1, u_2)^2}{\theta(u_1, u_2)_5^2}, \quad \frac{\theta(u_1 + e_1, u_2 + e_2)_3^2}{\theta(u_1 + e_1, u_2 + e_2)_5^2} = \frac{\theta(u_1, u_2)_5^2}{\theta^2(u_1, u_2)_5^2}.$$

$$\frac{\theta(u_1 + e_1, u_2 + e_2)_{1,3}^2}{\theta(u_1 + e_1, u_2 + e_2)_5^2} = \frac{\theta(u_1, u_2)_{1,3}^2}{\theta(u_1, u_2)_5^2}.$$

These three formulæ are fully proved by Königsberger, and present no difficulty. They are the result of the equations at the end of section 3 of the first memoir and of those at the beginning of this section. We therefore pass on to the theorems next enunciated, namely:—

$$\frac{d^2 \log_e \theta(u_1 u_2)_5}{du_1^2} = \frac{\frac{d^2\theta_5}{dv_1^2}}{\theta_5} + \frac{\left(\frac{d\theta_1}{dv_1}\right)^2}{\theta_5^2} \cdot \frac{\theta(u_1 u_2)_1^2}{\theta(u_1 u_2)_5^2}$$

$$+ \frac{\left(\frac{d\theta_3}{dv_1}\right)^2}{\theta_5^2} \frac{\theta(u_1 u_2)_3^2}{\theta(u_1 u_2)_5^2} + \frac{\left(\frac{d\theta_{1,3}}{dv_1}\right)^2}{\theta_5^2} \frac{\theta(u_1 u_2)_{1,3}^2}{\theta(u_1 u_2)_5^2},$$

with two similar expressions for

$$\frac{d^2 \log_e \theta(u_1 u_2)_5}{du_2^2} \text{ and } \frac{d^2 \log_e \theta(u_1 u_2)_5}{du_1 du_2}.$$

Take the equation at the commencement of p. 340,

$$\theta_5^2 \theta(u_1+v_1 \ldots .)_5 \theta(u_1-v_1)_5 = \theta(u_1 u_2)_5^2 \theta(v_1 v_2)_5^2$$
$$+\theta(u_1 u_2)_1^2 \theta(v_1 v_2)_1^2 + \theta(u_1 u_2)_3^2 \theta(v_1 v_2)_3^2 + \theta(u_1 u_2)_{1,3}^2 \theta(v_1 v_2)_{1,3}^2.$$

Expanding the members in terms of v, we have

$$\theta_5^2 \left\{ \theta(u_1 u_2)_5 + \frac{d\theta(u_1 u_2)_5}{du_1} v_1 + \frac{d^2\theta(u_1 u_2)_5}{du_1^2} \frac{v_1^2}{1.2} + \ldots . \right\}$$

$$\left\{ \theta(u_1 u_2)_5 - \frac{d\theta(u_1 u_2)_5}{du_1} v_1 + \frac{d^2\theta(u_1 u_2)_5}{du_1^2} \cdot \frac{v_1^2}{1.2} + \ldots . \right\}$$

$$= \left(\theta_5 + \frac{1}{2} \frac{d^2\theta_5}{dv_1^2} v_1^2 \right)^2 \theta(u_1 u_2)^2 + \left(\frac{d\theta_1}{dv_1} v_1 + \ldots . \right)^2 \theta(u_1 u_2)_1^2$$

$$+ \left(\frac{d\theta_3}{dv_1} v_1 + \ldots . \right)^2 \theta(u_1 u_2)_3^2 + \left(\frac{d\theta_2}{dv_1} v_1 + \ldots . \right)^2 \theta(u_1 u_2)_{1,3}^2.$$

Hence, equating coefficients of v_1^2, we find

$$\theta_5^2 \theta(u_1 v_2)_5 \frac{d^2\theta(u_1 \ldots .)_5}{du_1^2} - \theta_5^2 \frac{d\theta(u_1 u_2)_5^2}{du_1^2} = \theta_5 \frac{d^2\theta_5}{dv_1^2} \theta(u_1 u_2)^2$$

$$+ \frac{d\theta_1^2}{dv_1^2} \theta(u_1 u_2)_1^2 + \frac{d\theta_3^2}{dv_1^2} \theta(u_1 u_2)_3^2 + \frac{d\theta_{1,3}^2}{dv_1^2} \theta(u_1 u_2)_{1,3}^2,$$

from which the formula we desire to prove immediately follows. This demonstration will be understood, if we remember that

$$\frac{d\theta_5}{dv_1} = 0, \quad \theta_1 = 0, \quad \theta_3 = 0, \quad \theta_{1,3} = 0.$$

The formulæ for

$$\frac{d^2 \log_e \theta(u_1 u_2)_5}{du_2^2} \text{ and } \frac{d^2 \log_e \theta(u_1 u_2)_5}{du_1 du_2}$$

may be proved in a precisely similar manner.

Combining these three theorems with the last, we find

$$\frac{d^2 \log_e \theta(u_1+e_1, u_2+e_2)_5}{du_1^2} = \frac{d^2 \log_e \theta(u_1 u_2)_5}{du_1^2},$$

$$\frac{d^2 \log_e \theta(u_1+e_1, u_2+e_2)_5}{du_2^2} = \frac{d^2 \log_e \theta(u_1 u_2)_5}{du_2^2},$$

$$\frac{d^2 \log_e \theta(u_1+e_1, u_2+e_2)_5}{du_1 du_2} = \frac{d^2 \log_e \theta(u_1 u_2)_5}{du_1 du_2},$$

where

$$\theta(e_1, e_2)_1 = 0, \; \theta(e_1, e_2)_3 = 0, \; \theta(e_1, e_2)_{1,3} = 0. \quad \ldots \ldots \quad \text{(B)}$$

These equations, give by integration,

$$\theta(u_1+e_1, u_2+e_2)_5 = \epsilon^{pu_1+qu_2+r} \theta(u_1, u_2)_5.$$

whence we have

$$e_1 = m_1 + n_1\tau_{1,1} + n_2\tau_{1,2}, \quad e_2 = m_2 + n_1\tau_{2,1} + n_2\tau_{2,2},$$

which therefore constitute the solution of equation B.

Hence also the solution of the equations

$$\theta(w'_1 - w_1, w'_2 - w_2)_1 = 0, \ \theta(w'_1 - w_1, w'_2 - w_2)_3 = 0, \ \theta(w'_1 - w_1, w'_2 - w_2)_{1,3} = 0$$

is

$$w'_1 - w_1 = r_{1,1} + s_{1,1}\tau_{1,1} + s_{1,2}\tau_{1,2},$$
$$w'_2 - w_2 = r_{1,2} + s_{1,2}\tau_{2,1} + s_{1,2}\tau_{2,2},$$

where $r_{1,1}$, $r_{1,2}$, $s_{1,1}$, $s_{1,2}$ are any whole numbers. This formula then contains the required solution; and therefore, substituting for w, in the equations connecting u and w at the end of section (1), we have

$$(m-n)(\alpha K_{1,1} + \beta K_{2,1}) = C_{1,1}(r_{1,1} + s_{1,1}\tau_{1,1} + s_{1,2}\tau_{1,2}) + C_{1,2}(r_{1,2} + s_{1,1}\tau_{2,1} + s_{1,2}\tau_{2,2}),$$
$$(m-n)(\gamma K_{1,1} + \delta K_{2,1}) = C_{2,1}(r_{1,1} + s_{1,1}\tau_{1,1} + s_{1,2}\tau_{1,2}) + C_{2,2}(r_{1,2} + s_{1,2}\tau_{2,1} + s_{1,2}\tau_{2,2}).$$

We have already stated that this transformation corresponds to the periodic system

$$al\,(u_1 + 2K_{1,1}, u_2 + 2K_{2,1})^2_\alpha = al(u_1 u_2)^2_\alpha \text{ when } \alpha = 1 \text{ or } 3.$$

In the same way, if we take the periodic system

$$al(u_1 + 2K_{1,2}, u_2 + 2K_{2,2})^2_\alpha = al(u_1 u_2)^2_\alpha \text{ when } \alpha = 1 \text{ or } 3,$$

we have

$$(m'-n')(\alpha K_{1,2} + \beta K_{2,2}) = C_{1,1}(r_{2,1} + s_{2,1}\tau_{1,1} + s_{2,2}\tau_{1,2}) + C_{1,2}(r_{2,2} + s_{2,1}\tau_{2,1} + s_{2,2}\tau_{2,2}),$$
$$(m'-n')(\gamma K_{1,2} + \delta K_{2,2}) = C_{2,1}(r_{2,1} + s_{2,1}\tau_{1,1} + s_{2,2}\tau_{1,2}) + C_{2,2}(r_{2,2} + s_{2,1}\tau_{2,1} + s_{2,2}\tau_{2,2}).$$

We shall also have, if we take the periodic system

$$al(u_1 + 2iK'_{1,1}, u_2 + 2iK'_{2,1})^2_\alpha = al(u_1 u_2)^2_\alpha, \text{ where } \alpha = 1 \text{ or } 3,$$

$$i(m''-n'')(\alpha K'_{1,1} + \beta K'_{2,1}) = C_{1,1}(r'_{1,1} + s'_{1,1}\tau_{1,1} + s'_{1,2}\tau_{1,2}) + C_{1,2}(r'_{1,2} + s'_{1,1}\tau_{2,1} + s'_{1,2}\tau_{2,2}),$$
$$i(m''-n'')(\gamma K'_{1,1} + \delta K'_{2,1}) = C_{2,1}(r'_{1,1} + s'_{1,1}\tau_{1,1} + s'_{1,2}\tau_{1,2}) + C_{2,2}(r'_{1,2} + s'_{1,1}\tau_{2,1} + s'_{1,2}\tau_{2,2}).$$

Moreover, taking the system

$$al(u_1 + 2iK'_{1,2}, u_2 + 2iK'_{2,2})^2_\alpha = al(u_{1,1} u_2)^2_\alpha,$$

we shall have

$$i(m'''-n''')(\alpha K'_{1,2} + \beta K'_{2,2}) = C_{1,1}(r'_{2,1} + s'_{2,1}\tau_{1,1} + s'_{2,2}\tau_{1,2}) + C_{1,2}(r'_{2,2} + s'_{2,1}\tau_{2,1} + s'_{2,2}\tau_{2,2}),$$
$$i(m'''-n''')(\gamma K'_{1,2} + \delta K'_{2,2}) = C_{2,1}(r'_{2,1} + s'_{2,1}\tau_{1,1} + s'_{2,2}\tau_{2,2}) + C_{2,2}(r'_{2,2} + s'_{2,1}\tau_{2,1} + s'_{2,2}\tau_{2,2}).$$

Now we have already proved that

$$\tau'_{1,1} = \frac{i(K_{2,2}K'_{1,1} - K_{2,1}K'_{2,1})}{K_{1,1}K_{2,2} - K_{2,1}K_{1,2}}.$$

The equations we have just written down enable us to determine $K_{2,2}K'_{1,1}$, &c. in terms of $\tau_{1,1}$, $\tau_{1,2}$, $\tau_{2,2}$. Hence also $\tau'_{1,1}$ is known in terms of $\tau_{1,1}$, $\tau_{1,2}$, $\tau_{2,2}$, and $\tau'_{1,2}$; $\tau'_{2,2}$ can be determined in a precisely similar way. The remainder of the paper is occupied with the discussion of special cases, upon which I shall not enter, as Königsberger has gone minutely into details. There are two other papers by Königsberger on the transformation of hyperelliptic functions in the seventieth volume of Crelle, which we hope to consider in the supplement.

At the commencement of his paper Königsberger alludes to a paper on transformation by M. Hermite, in the 'Comptes Rendus' for 1855, from which I make the following extracts:—

Let $a_0a_1a_2a_3$, $b_0b_1b_2b_3$, $c_0c_1c_2c_3$, $d_0d_1d_2d_3$ be a system of entire numbers satisfying the equations

$$a_0d_1+b_0c_1-c_0b_1-d_0a_1=0,$$

$$a_0d_2+b_0c_2-c_0b_2-d_0a_2=0,$$

$$a_0d_3+b_0c_3-c_0b_3-d_0a_3=a_1d_2+b_1c_2-c_1b_2-d_1a_2=k,$$

$$a_1d_3+b_1c_3-c_1b_3-d_1a_3=0,$$

$$a_2d_3+b_2c_3-c_2b_3-d_2a_3=0;$$

also let

$$\theta(x, y)=(-1)^{mp+np}\epsilon^{i\pi((2m+\mu)x+(2n+\nu)y)}$$

$$\epsilon^{\frac{i\pi}{4}(G(2m+\mu)^2+2H(2m+\mu)(2n+\nu)+G'(2n+\nu)^2)};$$

then, if z_i denotes the linear function a_ix+b_iy, where i is one of the numbers 0, 1, 2, 3, and we assume

$$\theta(z_0+Gz_3+Hz_2,\ z_1+Hz_3+G'z_2)\epsilon^{i\pi(z_0z_3+z_1z_2)}$$

$$\epsilon^{i\pi(Gz_3^2+2Hz_3z_2+G'z_2^2)}=\Pi(x, y),$$

then

$$\Pi(x+1, y)=(-1)^{m_1}\Pi(x, y),\ \Pi(x, y+1)=(-1)^{n_1}\Pi(x, y),$$

$$\Pi(x+h, y+g')=(-1)^{p_1}\Pi(x, y)\epsilon^{-i\pi k(2y+g')},$$

$$\Pi(x+g, y+h)=(-1)^{q_1}\Pi(x, y)\epsilon^{-i\pi k(2x+g)},$$

where g, h, g' are certain ascertained functions of the above quantities, a, b, c, d, G, H, G' and m_1, n_1, p_1, q_1 certain ascertained functions of the quantities a, b, c, d, μ, ν, p, q.

And the method of transformation consists in introducing sixteen functions, $\theta^{(1)}$ analogous to θ, but in which G, H, G' are replaced by g, h, g', and then in employing the above relations to express $\Pi(x, y)$ by entire and homogeneous combinations of these sixteen functions.

I wish to remark that the proofs of Dr. Weierstrass's theorems, given in the Brighton volume, were obtained by me in the course of the year 1867. I had no assistance, except that derived from the Memoirs themselves.

Report of the Committee, consisting of the Rev. H. F. Barnes, H. E. Dresser (Secretary), T. Harland, J. E. Harting, T. J. Monk, Professor Newton, *and the* Rev. Canon Tristram, *appointed for the purpose of continuing the investigation on the desirability of establishing a "Close Time" for the preservation of indigenous animals.*

1. The apprehension expressed by your Committee in their last Report, as to the probable effects of the Wild-Birds Protection Act, has been more than justified by events; for, so soon as that Act came to be applied, it gave almost universal discontent, and your Committee have not found one person who is satisfied with it.

2. In the House of Commons, Mr. Auberon Herbert moved and obtained the appointment of a Select Committee to consider the subject of the Protection of Wild Birds.

3. Three members of your Committee, on being summoned, gave evidence before the Select Committee of the House of Commons.

4. The Report of the Select Committee of the House of Commons has not, to your Committee's regret, yet been published, but your Committee have good reason for believing that it will contain the following recommendations:—

"(i.) That the protection of certain wild birds named in the Schedule of the Wild Birds-Protection Act of 1872 be continued.

"(ii.) That all other wild birds be protected from 15th March to 1st August, provided that owners or occupiers of lands, and persons deputed by them, have permission to destroy such birds on lands owned or occupied by them.

"(iii.) That one of Her Majesty's Secretaries of State be empowered to except, in any particular district, any bird from the protection afforded, either by the Act of 1872 or by the proposed Act, if he think necessary to do so.

"(iv.) That, for the sake of giving better protection to the swimmers and waders, no dead bird, if such bird is mentioned in the Sea-Fowl Preservation Act, or the Wild-Birds Protection Act of 1872, be allowed, from 15th March to 1st August, to be bought and sold, or exposed for sale, whether taken in this country or said to be imported from any other country.

"(v.) That any violation of this proposed Act, or of the Wild-Birds Protection Act of 1872, be punished by the payment of costs alone for the first offence, except under aggravated circumstances, and the payment of costs and a fine not exceeding 5*s*. for every offence after the first."

5. Your Committee wish emphatically to condemn these recommendations as a whole, and all but one of them separately, for the following reasons, numbered as are the recommendations:—

i. The great majority of the birds named in the Schedule of the Act of 1872 do not require protection, as has been shown in former Reports of your Committee; they therefore think that in the present state of public opinion it is inexpedient that such protection should be accorded to them.

ii. That for the sake of protecting other wild birds, most of which certainly do not want protection, rights would be continued to owners and occupiers of land which would be denied to other

persons: consequently the principle of privilege, usually urged as one of the strongest objections to the Game Laws of this country, would be introduced into the proposed Act, which would thereby be subject to the attacks of all those who are opposed to those laws. Further, that if there be any need to protect such other wild birds, the need is greater, in most cases, to protect them from the owners and occupiers of land than from other persons.

iii. That the power to be given to the Secretary of State would virtually be that of repealing the Act, either entirely or in regard to any particular kind or kinds of birds, at his sole will and pleasure, without his acting on the opinion of any responsible adviser or expert assessor; and that in consequence of such unlimited power being intrusted to a high officer of State, who cannot be expected to have any personal knowledge of the intricacies of the questions involved, the results would in most cases be highly unsatisfactory to all persons concerned, it being also taken into consideration that the state of the law would vary very considerably in different parts of the country, even perhaps in different parts of the same county. Furthermore, the granting of such power to any authority presumes that some kinds of birds would be at once exempted from protection, which is tantamount to inviting persecution on such kinds of birds as would be included in what has been termed a "Black List."

iv. With this recommendation your Committee have the pleasure of entirely concurring.

v. The anticipation of your Committee, that the penalties imposed by the Act of 1872 would be found insufficient, having been proved by experience to be true, your Committee consider that the proposed increase of such penalties is quite inadequate to secure efficiency to the new Act—regard, however, being had to the indefinite phrase, "except under aggravated circumstances," the meaning of which your Committee cannot explain.

Finally, your Committee wish to point out that, so far as they have the means of knowing the nature of the evidence given before the Select Committee of the House of Commons, the four recommendations which they condemn are directly opposed to that evidence.

6. The increasing interest taken by the public generally in the question which your Committee have been now for five years appointed to investigate, is shown by signs too numerous to mention. Your Committee, however, observe with regret that in the minds of some persons it has been mixed up, if not confounded, with other questions which are entirely distinct. Two of these may be specified—(1) the Utility of Birds to Agriculturists, and (2) the State of the Law as regards Cruelty to Animals. Your Committee not having been appointed to consider these questions, content themselves with remarking that both are doubtless of great importance to the community, the one from a moral and the other from a material point of view, but are likewise entirely outside the duty of your Committee.

7. In order to assist the clearer view which your Committee hope that the public will in time take of the question of Bird-protection, your Committee unanimously beg leave to submit for consideration the following remarks as to any future legislation:—

(1) However much we may desire it, we cannot in practice stop the killing of some birds during the breeding-season: if we pass a law totally prohibiting it, that law will either be evaded, or, if enforced, will become so irksome as to be speedily repealed.

(2) No law, to be effectual, should pick and choose certain kinds of birds, leaving out nearly allied kinds.

(3) An effectual law, dealing with a whole group of birds, may be passed, as witness the highly successful 'Sea-Birds Preservation Act.'

(4) A law protecting birds which cannot be shown to want protection is a mistake.

(5) The crucial test of whether a bird wants protection or not, is whether its numbers are decreasing or the contrary.

(6) With some very few exceptions (nearly each of which can be satisfactorily explained), none of what are commonly known as "Small Birds" are decreasing throughout the United Kingdom generally.

(7) Most "Small Birds" are generally increasing in numbers, some remarkably so.

(8) Setting aside "Sea-Birds," which may now be considered safe, no birds have so much diminished in numbers as "Birds of Prey" and "Wild Fowl."

(9) No law for the protection of "Birds of Prey," if passed, could be at present carried out.

(10) A law protecting "Wild Fowl," if passed, could be carried out effectually, provided that the penalties are in proportion to the inducement to break it.

(11) "Wild Fowl" form a group subject to great persecution on account of their marketable value, especially as articles of food: they are commonly killed (many of them because then more easily killed) long after they have paired and have begun to breed; they, besides, lie under the same disadvantage as do the few "Small Birds" which are decreasing—the diminution, namely, through agricultural improvements, of their breeding-haunts: already many kinds of "Wild Fowl," which a few years ago used to breed frequently and regularly in this country, have ceased or nearly ceased from doing so: they are perfectly innocuous; consequently "Wild Fowl" are eminently deserving of protection.

(12) The principle of what has been called a "Black List," favoured by some persons, would be the most fatal step of all in Bird-Protection, since it would discourage, if not entirely check, the healthy feeling which is steadily, if not rapidly, growing in favour of many birds which have long been persecuted.

8. Your Committee respectfully urge that they may be reappointed.

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Report of the Committee, consisting of James Glaisher, *F.R.S., of the Royal Observatory, Greenwich,* Robert P. Greg, *F.G.S., and* Alexander S. Herschel, *F.R.A.S., on Observations of Luminous Meteors,* 1872–73; *drawn up by* Alexander S. Herschel, *F.R.A.S.*

The observations of meteors and shooting-stars collected during the past year have been of a more than usually interesting and varied character. The number of large meteors is more considerable; and the appearances of ordinary shooting-stars have presented themselves in a more striking manner as regards the explanation of their origin than has often been the case in former years. Of the meteors which have thus appeared, the Committee have obtained much accurate information: but the extent of the knowledge acquired on all hands of the origin of these bodies has advanced so rapidly with the increase of such observations, that a smaller space for discussion of the individual descriptions can be occupied in their Report than the Committee have hitherto been able to bestow upon them; and a more complete reduction of the separate observations will accordingly be attempted when the opportunities of the Committee allow of their closer examination. Those meteors, however, which have been observed simultaneously at more than one observing-station, have been selected from the collection for transcription in suitable columns in this Report; and a list of large meteors is added, among which some have occurred that have without doubt been noticed, and may have attracted attention, in other directions than has hitherto come to the knowledge of the Committee. Two of the largest fireballs seen in Great Britain were aërolitic, or burst with the sound of a violent explosion, on the 3rd of November and 3rd of February last, over the interior of Scotland and over Manchester and its neighbourhood respectively. The descriptions of these two meteors are not so accurate and complete as to admit of very useful repetitions of all their details. Aerolitic meteors and aerolites have also been noticed in the scientific journals of other countries, which have given rise to experiments on the composition of aërolitic substances, both chemical and microscopical, the conclusions of which continue to extend the range of our speculations regarding the origin of these bodies. Thus the existence of carbon and hydrogen in the atmosphere from which the largest iron meteorite yet found (on the shores of Greenland) was projected, confirms the discoveries of Graham and Dr. Mallet, of the existence of those gases in other meteoric irons which have recently been examined, and offers proofs of a relationship between meteorites and comets (in whose spectra carbon has been recognized as an ingredient) which it will be interesting to pursue with further experiments and observations.

The past year was distinguished by the occurrence of a most remarkable and striking star-shower on the night of the 27th of November last, to the expected appearance of which astronomers were looking forward with especial attention, from the unexplained absence of the double comet of Biela (to which it belongs) at the time of its expected returns in the last three of its periodical revolutions. The probability of the comet's path being marked by a meteoric stream, into which the earth might plunge on or about the 27th of November every year, was already become a certainty by the observation by Zezioli, of Bergamo, of such a meteoric shower on the 30th of November, 1867, no doubt of whose belonging to the path of the missing comet could possibly be entertained. The exact date of the shower could not be foretold with

certainty, from the want of recent observations of the comet; but every probability of its being seen was favourable to its reappearance last year; and those who awaited it, as well as many unexpectant watchers of meteor-showers, were surprised by the display of shooting-stars which it suddenly presented at the first approach of darkness, on the evening of Wednesday the 27th of last November. The cloudy state of the sky unfortunately prevented observers throughout the south of England from witnessing the sight; but in Scotland and north of the Midland Counties in England many uninterrupted views of it were obtained. In Europe, Asia, the Mauritius, and in North and South America observers were equally fortunate in recording its appearance; and few great star-showers have hitherto been more satisfactorily observed, as well as more abundantly described. In an astronomical point of view, the agreement of the time and other circumstances of its appearance with the supposed path of the lost comet is so exact as to prove that the calculations made by astronomers of that comet's orbit cannot be affected by any errors of a large amount; and a proof almost certain is thus obtained that the disappearance of the comet is owing to no unexplained disturbances of its path; but that, like some former comets of variable brightness, it has not improbably faded for a time out of view, and that at some future time a reasonable expectation may be entertained of rediscovering the missing comet pursuing its original path in repeated visits to the earth's neighbourhood and to the field of telescopic observations.

Only partial views of the ordinary periodical meteoric showers of December, January, and April last have this year been obtained, of which some descriptions are added to the close of this Report. Reductions of the scattered meteor-observations on ordinary nights of the year are an important subject of the Committee's inquiries, which have been kept in view in their operations of the past year. Captain Tupman having obligingly placed a list of nearly 6000 such observations (made by himself) at their disposal, the greater part of which he has reduced to their most conspicuous radiant-points, this special object of the Committee will be most effectually assisted by the publication of the valuable meteor list which has thus unexpectedly come into their possession. A graphic projection of the radiant-points has been prepared, which will be printed as an illustration of the copious information that will be gathered by observers from the contents of Captain Tupman's list. The catalogue will be distributed this year to observers interested in the research; and to enable useful meteoroscopic charts to be added to it, it is hoped that the Members of the British Association will continue to assist the Committee with such liberal communications of their observations as they have hitherto supplied.

APPENDIX.

I. Meteors Doubly Observed.

In the section of the last Report corresponding to this Appendix, a considerable list of simultaneous observations of shooting-stars in the August and other meteor-showers of the previous year was presented of which no calculations had at that time been undertaken. The attention of the Committee having been much occupied during the past year with the questions and correspondence relating to the unusual meteor-display of the 27th of November last, their intention of calculating these meteor correspondences has not been carried out; and a large addition to the number of duplicate observations of

Date.	Hour, Approx. G. M. T.	Places of Observation.	Apparent Magnitudes.	Duration.	Heights in B. S. miles at Beg.	Heights in B. S. miles at End.	Length of Path.	Velocity.	Radiant-point.
1872.	h m s			secs.	Beg.	End.	miles.	miles per second.	
August 10	10 53 30	Greenwich......... ... Tooting .... Birmingham	Sirius .... > ♃ . ... > 1st mag...	2·0 1·5 1·0	95	70	47	37·2	$\alpha=85°$ $\delta=+63°$ (Near *d* Camelopardi.)
1873.									
April 19	10 43 0	York .. .. Newcastle-on-Tyne ..	1st mag....... $1\frac{1}{2}$ mag	About 1·2 1·1	55	47	38	About 33·5	$\alpha=278°$ $\delta=+26°$ (Between Lyra and Cerberus.)
April 20	10 22 30	Sunderland .... Newcastle-on-Tyne ...	2nd mag ... $1\frac{1}{2}$ mag	...... 0·6	58	40	.	......	$\alpha=256°$ $\delta=+35°$ (Near π Herculis.)
April 20	11 7 0	Sunderland .... Newcastle-on-Tyne ...	4th mag. ... 4th mag. ...	...... 0·8	34	30	...	......	Ursa Major, or a more northern Radiant-point.
April 20	11 15 0	Sunderland .... Newcastle-on-Tyne ...	2nd mag. ... $3\frac{1}{2}$ mag.	...... 0·6	98	69	...	...	In Hercules or Cerberus.
			Average Heights	......	68	51			

shooting-stars in subsequent meteor-showers has in the mean time been collected, of which (for the same reason) it is only possible to offer in this Report the materials for such a future computation of their comparative results. The following list contains the particulars of a great many such observations, of which the Committee are obliged for the present to leave the calculation to a more convenient opportunity; and a few results obtained by a rapid graphical projection of the paths of a few conspicuous meteors of the list at the moment when the observations were received, are all the results of their final comparison together which the Committee are now able to present.

Two bright meteors were seen, one at Glasgow and one in South Wales, on the night of the 9th of October last; and again two separate meteors, no less bright, at Glasgow and its neighbourhood, and at Bristol and Portsmouth on the night of the 3rd of November, 1872. Of the latter two meteors only, duplicate observations were received; and the observations on this night appear to indicate an extraordinary frequency of bright meteors. Thus at Milngavie, near Glasgow, "On Sunday evening (November 3rd) a shower of exceedingly brilliant meteors was observed falling; one of these was particularly brilliant, &c." It appeared in the north, and left for a second or two a line of light resembling the tail of a comet. The description of the meteor is the same at Leshmahagow, where it is added that, after being observed, it remained in one position and thereafter took an onward course with a rapid flight westwards until it was exhausted. The pause in its flight and the accompanying tail of sparks are well described by Mr. M'Clure in the list of duplicate observations. The daily newspapers at Glasgow describe it as passing there from east to north-west or west, appearing as a large bluish fireball with a long tail consisting of coruscations of red light. The Rev. A. Johnson, of Cambuslang, near Glasgow, describes it as of yellow colour, moving about 45° above the horizon from a little south of east to north of west, throwing out a red tail and brilliant bluish and greenish sparks as it seemed to curve downwards a little in the latter part of its course. The remaining description at Melrose of this meteor's appearance (see the list) is too imperfect to afford, with Mr. M'Clure's account at Glasgow, a definite conclusion of its height; but the interrupted speed and curved course which seem to have marked its motion there, probably signify that the meteor's flight, as seen at Glasgow, was foreshortened near its radiant-point, and that this point was accordingly near Perseus, Andromeda, and Auriga. This meteor detonated, being seen and heard to explode at the same time in the north of Scotland. It appeared at half-past five o'clock. The observed paths of the next large meteor on the same evening at Portsmouth and Bristol at a quarter past nine o'clock, proceeded from the same radiant-point, and, together with a few observations of bright shooting-stars on the same date observed elsewhere, mark the neighbourhood of a point near β Persei at about R. A. 45°, N. Decl. 35°, as roughly representing a region of radiation of the bright meteors recorded on this date. On the night of the 30th of October Mr. Backhouse noticed a great many meteors at Sunderland, four of which had a radiant-point in Cassiopeia at 0°, +55°; eight or ten others diverged from near γ, λ Ceti (at about 40°, +6°), and a few others apparently from near ϵ Piscium (at about 14°, +7°), all of their radiant-centres being in the neighbourhood of the above-mentioned radiant-regions. Besides these, Captain Tupman observed a shower of ten bright meteors in forty minutes on the night of November 1st, with three others from the same direction in about the same time on the night of November 3rd, having a definite radiant-point at 56°, +24°, close to the place assigned to a similar meteor system as seen by Mr. Backhouse on the nights

of the 4th and 6th of November, 1869 (these Reports for 1870, p. 97), coinciding exactly with Heis's radiant R_4, and very nearly with No. 111 of Mr. Greg's general list (R G) at 64°, +18°. Several meteors from a radiant-point nearer to the latter position, at 64°, +20°, were observed by Mr. Denning at Bristol, on the nights of the 6th, 9th, and 10th of November last. On the first of these nights a meteor also proceeded from the direction of a radiant-point in Auriga, at about 85°, +27°; and on the last date Mr. C. E. Baker, at Bristol, noted five meteors diverging from a common radiant-point near the Hyades, in Taurus. The whole of these affiliated radiant-points appear to be connected with the well-known shower from near α Tauri, often noticed by observers during long watches for the Leonids or meteors of the 14th of November, having its time of maximum from October 30th to November 6th, or in the first few days of November.

The next considerable meteor of which duplicate observations were obtained, appeared at about ten o'clock on the evening of the 3rd of February, 1873. Owing to the cloudy and hazy state of the sky, which nearly concealed the moon at many places, the descriptions of its apparent path were nowhere sufficiently determinate to indicate its real course with great precision; but they combine to show that the meteor moved at a lower elevation than common amongst ordinary shooting-stars, over the northern part of Staffordshire and Cheshire, passing at a height of less than forty miles above Crewe, and disappearing at a height of less than thirty miles over a point between Liverpool and Chester: at some point of this course a violent explosion was produced, the sound of which was heard like the loud boom of a distant gun or a low roll of thunder about three or four minutes after the meteor's disappearance. The accounts of its apparent path, and also of the time and character of the occurrence of the report, are very discordant; but there appears no doubt that the meteor was a detonating fireball of the largest class, illuminating the whole country over which it passed with one or two prolonged flashes of light at least as powerful as that of the full moon, and the report differing altogether from that of any signal gun, of which it is said that one took place at about the time of its appearance. Its course may also have been rather more nearly from east to west, or from over Chesterfield to above Chester, than that above described, the best descriptions at Manchester and Sheffield stating that it vanished at its extinction near and directly above the moon, which was then shining in the west. The light of the meteor was bluish, with a train of many brilliant sparks in its track; and it burst into many fragments, but without leaving any visible streak of light in its course. Mr. Greg, Mr. Wood, and Mr. Sorby have collected numerous descriptions of this meteor's appearance at Manchester, Birmingham, and Sheffield; but the definite results to which they all point, scarcely vary sufficiently from the above general conclusions to make their separate enumeration necessary to complete this notice. It is remarkable, as observed by Mr. Wood, that on the same date and at the same local time of the evening, a very brilliant fireball was visible in Australia, of which a description appeared in the 'English Mechanic' of May 2nd, 1873, p. 171.

APPARENT PATHS OF METEORS DOUBLY

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1870. Nov. 13	h m s 9 38 0	Radcliffe Observatory, Oxford.	> ♃	Blue............	4 seconds......	From near Capella to near Omicron, Ursæ Majoris.
1871. Aug. 10	10 57 0 (Paris time.)	Luxembourg Observatory, Paris.	Very bright meteor	....	....	$\alpha=$ $\delta=$ From 247°+33° to 251 +13
1872. July 22	8 55 p.m.	Bridgewater (Somersetshire).	= Sirius.	Orange-red ...	1·25 second ...	*For* 5° N. of East *read* 13° N. of East.
Aug. 8	10 29 16	Bangor, N. Wales	3rd mag.	....	Very swift; 0·2 second.	$\alpha=$ $\delta=$ From 309°− 3° to 300 −15
8	10 30 0	Royal Observatory, Greenwich.	3rd mag.	....	....	From 221°+37°·7 to 226 +22·7
8	10 39 19	Bangor, N. Wales	3rd mag.	....	Very swift; 0·2 second.	From 352°+9° to 344 −1; passing right across the small star at 347°, +3°.
8	10 40 0	Royal Observatory, Greenwich.	1st mag.	....	....	$\alpha=$ $\delta=$ From 222°·5+65° to 221 +46; passed through 39 Boötis.
8	11 36 23	Ibidem...........	1st mag.	Bluish white .	1 second	Passed towards the horizon in continuation of a line joining α Persei and *c* Camelopardi.
8	11 37 0	Radcliffe Observatory, Oxford.	2nd mag...........	....	1 second	From α Persei to β Camelopardi.
8	11 38 3 ± 15s, G. M. T.	Lancaster........	2nd mag...........	....	....	Passed close to the star 20 Pegasi.
8	11 55 33	Ibid..............	2nd mag...........	....	....	Passed close to the star 55 Pegasi.

OBSERVED DURING THE YEAR 1872–73.

Length of Path.	Direction or Apparent Radiant-point.	Appearance ; Remarks.	Observer.
....	....	[Also observed at the Royal Observatory Greenwich. See Report for 1871, page 34.]	J. Lucas (Radcliffe Observations, 1869).
....	....	A very brilliant meteor. [Corresponds nearly, but is *not* identical with that seen in England at $10^{h}\ 51^{m}$ G. M. T. See last Report, page 80.]	Chapelas Coulvier Gravier.
For 20° *read* 35° or 40°.	Slope about 35°	*For* β Pegasi *read* Altair. *Add* Place of disappearance as measured by a house-corner close to which it disappeared. [Corrections in last Report, p. 118.]	J. E. Clark.
....	Perseïd............................	Good general position, fair direction, and doubtful point of disappearance of path.	G. L. Tupman.
....	....	Disappeared behind dome of the Sheepshanks Equatorial. A good observation.	G. Forbes.
....	Perseid............................	General position of path accurate; direction and point of disappearance uncertain.	G. L. Tupman.
....	....	A fairly good observation	G. Forbes.
8°............	....	Left a streak	T. Wright.
....	....	....	J. Lucas.
....	Slope of path 45° .... ↙	....	W. Davenport.
....	Slope of path 45° .... ↙	....	Idem.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1872. Aug. 8	h m s 11 55 38	Royal Observatory, Greenwich.	2nd mag.	....	0·3 second ...	Passed horizontally about 6° below Polaris.
8	11 56 0 (± 30^s.)	Ibid...............	3rd mag.	....	0·75 second...	α= δ= From 167°·5+71° to 188·5 +52
8	11 56 0	Radcliffe Observatory, Oxford.	2nd mag...........	....	1 second	Shot from near γ Persei.
8	12 58 0	Ibid...............	3rd mag.	....	....	From 13 [*d*] Camelopardi [74°·4+62°·3] to β Aurigæ.
8	12 58 45	Royal Observatory, Greenwich.	1st mag.	Bluish white .	0·7 second ...	Passed between α and τ Ursæ Majoris.
10	10 25 0	Buntingford, Herts.	1st mag.	White	1 second	α= δ= From 346°+25° to 335 +10 (Apparent course as mapped.)
10	10 27 0	Regent's Park, London.	1st mag.	Bluish white .	Swift	α= δ= From 30°+58° to 27 +77
10	10 27 35	Prior Street, Greenwich.	3rd mag.	Bluish white .	0·7 second ...	Passed across γ Cephei.
10	10 46 45	Ibid...............	1st mag.	Bluish white .	1 second	Passed a little below κ Honorum [Andromedæ] to a point between α and β Pegasi.
10	10 47 0	Tooting, near London.	....	White	1 second	Passed above α Andromedæ.
10	10 52 0	Birmingham ...	Sirius	Orange........	1 second	α= δ= From 355°+8° to 347 −8
10	10 53 30	Prior Street, Greenwich.	>1st mag.	Bluish white; changed to flame-colour.	2 seconds......	From between ζ and ξ Cassiopeiæ; passed to a point a little below β Pegasi.
10	10 54 0	Tooting, near London.	>♀	Dazzling white	1·5 second ...	α= δ= From 0°+37° to 349 +22 [Apparent course as mapped.]
10	11 18 0	Radcliffe Observatory, Oxford.	=3rd mag.........	White	0·5 second ...	From λ Persei to ε Aurigæ.
10	11 18 30	York...............	=Sirius	Blue...........	1 second	α= δ= From 14°+32° to 8 +18

Length of Path.	Direction or Apparent Radiant-point.	Appearance; Remarks.	Observer.
1°		Left no streak	R. Cross.
		Left a streak for 0·25 second	G. Forbes.
	Horizontal ←	Left a streak	J. Lucas.
		Left a streak	Id.
	Moving from Cassiopeia towards β Ursæ Majoris.	Left a streak	W. C. Nash.
12°	Radiant, η Persei	Left a streak for 1 second	R. P. Greg.
			T. Crumplen.
7°	Directed from f Custodis	Left a streak	W. Marriott.
15°		Left a fine streak	Id.
	On a line from the upper part of Perseus towards α Pegasi.	The stars in Perseus and Pegasus much obscured by clouds.	H. W. Jackson.
		Left a streak for 3 seconds	W. H. Wood.
20°		Left a magnificent train, which lasted 3 or 4 seconds after the disappearance of the meteor.	W. Marriott.
	As from χ Persei towards α Pegasi.	Left a streak for 1 or 2 seconds. Position carefully observed.	H. W. Jackson.
		Left a streak	J. Lucas.
14°·5		Left a streak for one second. Followed in thirty seconds by another meteor as bright as Venus; on the same course.	J. E. Clark and T. H. Waller.

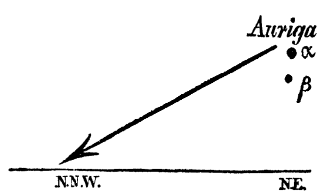
Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1872.	h m s					
Aug. 10	11 28 0	York	2nd mag.	White	0·5 second	$\alpha=$ $\delta=$ From 319°+70° to 289 +60
10	11 29 0	Radcliffe Observatory, Oxford.	4th mag.			Passed from ι to χ Ursæ Majoris.
10	11 34 0	Ibid	2nd mag.	White	1·5 second	Passed from δ to β Aurigæ.
10	11 34 0	York	Sirius	Red	1·5 sec.; slow.	$\alpha=$ $\delta=$ From 6°+30° to 8 +20
10	11 40 0	Radcliffe Observatory, Oxford.	4th mag.			From δ Ursæ Majoris to α Canum Venaticorum.
10	11 42 0	Birmingham	3rd mag.	Blue	0·5 second	$\alpha=$ $\delta=$ From 284°+70° [? 194 +70] to 197 +57
10	11 44 0	York	3rd mag.	Red	1 second	From 38°+51° to 35 +49·5
10	11 45 0	Radcliffe Observatory, Oxford.	4th mag.			Shot from near δ Aurigæ.
10	11 46 0	Ibid	5th mag.			Passed from ι to χ Ursæ Majoris.
10	11 46 30	York	1st mag.	Blue	0·75 second	$\alpha=$ $\delta=$ From 339°+67° to 306 +63
10	12 7 0	Birmingham	3rd mag.	Blue		From β Aquarii to α Sagittarii.
10	12 9 1	Royal Observatory, Greenwich.	1st mag.	Bluish white		Fell almost vertically downwards from ζ Aquilæ.
10	12 20 0	Birmingham	1st mag.	Yellow		Shot from β towards ζ Andromedæ.
10	12 20 53	Royal Observatory, Greenwich.	1st mag.	Bluish white	1·2 second	Disappeared near ϵ Ursæ Majoris.
11	10 25 30	Ibid	2nd mag.		0·5 second	$\alpha=$ $\delta=$ From 210°+40° to 197·5+20
11	10 26 0	Radcliffe Observatory, Oxford.	2nd mag.	White	Rapid	From ι Draconis to η Ursæ Majoris.
11	10 26 30	Royal Observatory, Greenwich.	1st mag.		1 second	$\alpha=$ $\delta=$ From 220°+35° to 200 +27
11	10 27 0	Radcliffe Observatory, Oxford.	3rd mag.	White	Rapid	Passed from above Corona to η Ursæ Majoris.

Length of Path.	Direction or Apparent Radiant-point.	Appearance; Remarks.	Observer.
15°	....	Left a streak for ½ a second	J. E. Clark and T. H. Waller.
....	....	....	J. Lucas.
....	[Directed from Polaris].........	....	Id.
10°·5	Radiant Polaris	Left no streak at all on its course. The nucleus had an almost sensible diameter; not bright for its size. The second meteor seen from the same radiant.	J. E. Clark and T. H. Waller.
....	....	....	J. Lucas.
....	Radiant χ Persei........	[A doubtful agreement in time with the last meteor. The recorded path being also unconformable to the assigned radiant-point.]	W. H. Wood.
2°·5	[Foreshortened path, near the radiant in Perseus.]	Left no streak........................	J. E. Clark and T. H. Waller.
....	....	....	J. Lucas.
			
....	....	[Probably identical with the next meteor.]	Id.
14°	....	Left a very bright streak for 2 seconds.	J. E. Clark and T. H. Waller.
....	....	....	W. H. Wood.
10°	....	Left no streak........................	T. Wright.
>10°	....	Left a streak. View of its flight partly intercepted by clouds.	W. H. Wood.
16°	From the direction of Polaris...	Left a streak	W. A. Schultz.
....	....	The observed position not very accurate.	G. Forbes.
....	....	....	J. Lucas.
....	....	The observed position fairly accurate.	G. Forbes.
....	....	....	J. Lucas.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1872. Aug. 11	h m s 10 32 0	Radcliffe Observatory, Oxford.	4th mag.	White	Rapid	Passed from ι Ursæ Majoris towards the north horizon.
11	10 32 0	Birmingham	2nd mag.	Yellow	0·75 second	$\alpha=$ $\delta=$ From 95° +56° to 101 +53
11	10 38 0	York	1st mag.		0·75 second	From 356° +12° to 318 0
11	10 39 0	Birmingham	1st mag.	Yellow	1 second	From 52° +40° to 38 +31
11	10 51 0	Ibid.	4th mag.	Blue	0·5 second	From β Pegasi to α Aquarii.
11	10 51 30	Royal Observatory, Greenwich.	4th mag.			In Draco
11	10 56 0	Birmingham	2nd mag.	Yellow	>0·5 second	$\alpha=$ $\delta=$ From 326° 0° to 323 −7
11	10 57 30	Royal Observatory, Greenwich.	1st mag.		1 second	From 273° +35° to 267·5 +15
11	11 1 17	Ibid.		Bluish white	0·8 second	Shot between β and γ, about 2° from γ Ursæ Majoris.
11	11 3 0	York	2nd mag.	Red	1 second	$\alpha=$ $\delta=$ From 285° +45° to 262 +32
11	11 6 0	Regent's Park, London.	1st mag.	Blue		From 115° +72° to 166 +56 [Apparent course as mapped.]
11	11 7 0	Royal Observatory, Greenwich.	3rd mag.		1 second	$\alpha=$ $\delta=$ From 150° +64° to 162·5 +53
11	11 7 0	York	= ♀	Blue	0·75 second	From 321° +28° to 309 +15
11	11 10 30	Royal Observatory, Greenwich.	3rd mag.		0·5 second	From 150° +61° to 160 +52
11	11 10 52	Ibid.		Bluish white	0·8 second	Passed between α and δ Ursæ Majoris.
11	11 11 0	York	= ♀	White	0·75 second	$\alpha=$ $\delta=$ From 322° +58° to 300 +43
11	12 11 0	Buntingford, Herts.	2nd mag.	Bluish white	1 second	From 323° +34° to 308 +12 [Apparent course as mapped.]
11	12 11 10	Prior Street, Greenwich.	1st mag.	Bluish white	1 second	Shot from between γ and ϵ Cygni in the direction γ Aquilæ.
11	12 18 0	Buntingford, Herts.	Sirius	Bluish white	1 second	$\alpha=$ $\delta=$ From 31° +17° to 30 +6 [Apparent course as mapped.]

Length of Path.	Direction or Apparent Radiant-point.	Appearance; Remarks.	Observer.
....	....	....	J. Lucas.
....	....	Left a streak	W. H. Wood.
14°	....	Left a streak for 2 seconds	J. E. Clark and T. H. Waller.
....	....	Left a streak	W. H. Wood.
....	....	....	Id.
....	....	....	G. Forbes.
....	....	Left a streak	W. H. Wood.
....	....	Left a streak for half a second. Position moderately well observed.	G. Forbes.
10°	Almost perpendicularly downwards.	....	R. Cross.
22°	....	....	J. E. Clark and T. H. Waller.
....	....	Left a very bright streak	T. Crumplen.
....	....	Left a streak for half a second. Good observation of position.	G. Forbes.
17°	Perseïd.....................	Left a streak for 2½ seconds	J. E. Clark and T. H. Waller.
....	....	A very good observation of position.	G. Forbes.
10°	From the direction of Polaris...	Left a streak	R. Cross.
23°	Perseïd.....................	A streak, if any left, was obscured by clouds.	J. E. Clark and T. H. Waller.
20°+	Radiant η Persei	Left a streak for 1 second	R. P. Greg.
15°	....	Left a streak	W. Marriott.
10°	Radiant η Persei............	Left a streak for 1 second	R. P. Greg.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1872. Aug. 11	h m s 12 19 25	Royal Observatory, Greenwich.	....	Yellowish......	1·3 second ...	Shot downwards from a point about 15° above them, towards the Pleiades.
11	12 19 28	Prior Street, Greenwich.	>1st mag.	Bluish white .	1 second	Shot from the direction of ϵ Persei in the direction of ϵ Arietis. (Approximate position.)
19	8 47 0	Radcliffe Observatory, Oxford.	1st mag.	Yellow to green.	2·5 seconds ...	From ω Aquilæ to near δ Aquilæ.
19	About 8 50 0	Bristol	>1st mag.	Bright blue ...	Moved slowly	Passed down the E.N.E. sky.
Nov. 3	5 30 0	Glasgow (Scotland).	$\frac{1}{3}$ apparent diameter of the moon.	Vivid green to bluish white, with red sparks.	2·5 seconds; not rapid.	Began about 10° left of Capella, and disappeared behind a cloud near the N.N.W. horizon.



3	5 30 0	Melrose (Scotland).	Very large and bright.	Pink, green, blue, and white.	Moved so slowly that it could be well observed.	The line of its flight was from E. to N.W.
3	9 14 0	Portsmouth ...	Nucleus about 10′ in diameter.	Red and yellow	3·5 seconds ...	From $\alpha=57°$ $\delta=+69°$ to 135 +67·5. From near γ Camelopardi (m Custodis) to ρ Ursæ Majoris.

Length of Path.	Direction or Apparent Radiant-point.	Appearance; Remarks.	Observer.
13°	....	Left a very fine train	R. Cross.
15°	....	Left a streak	W. Marriott.
....	....	[A fine meteor; radiant apparently near γ Draconis. A bright meteor was seen at a later hour of the same night at York. See the accompanying list.]	J. Lucas.
... .	....	Nucleus starlike; left no streak of light on its course. It did not explode, but seemed to burn out gradually.	W. F. Denning.
....	....	Nucleus with short red tail, accompanied in the latter portion of its flight by a shower of red sparks. About the middle of its path its velocity decreased as if the fireball were passing through a denser medium, thereafter pursuing its path with renewed velocity.	Robert M^c^Clure.
....	....	The train was a mixture of many colours. The nucleus exploded with a shower of sparks. [Its red coruscations and flight from E. to W. in the north was observed at many places near Glasgow. See Appendix II.]	A. Dodds. Communicated by G. J. Symons.
....	γ Andromedæ, radiant of Biela's comet (?).	Exceedingly brilliant. Commenced as an ordinary shooting-star, and increased until it greatly surpassed Venus at her greatest brilliancy; with a long train of sparks, but leaving no streak upon its course. The observed position very accurate.	G. L. Tupman.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1872. Nov. 3	h m s About 9 15 0	Bristol	Very bright meteor	....	....	Appeared at a point near the zenith, and passed downwards about 10° E. of the Pleiades in Taurus.
28	10 25 0	Regent's Park, London.	1st mag., bright ...	Bluish	Moved slowly	$\alpha=$ $\delta=$ From 73°·5 +29° to 88 +35·5
28	10 29 0 (approx. time).	Hawkhurst (Kent).	1st mag.	....	Rather slow speed.	Began near *b* Camelopardi.
1873. Feb. 3	9 58 0	Bristol	Large meteor	....	....	Flash of the meteor behind clouds near the horizon, about 10° E. of N. or at N. by E.
3	About 10 0 0	Wordsley, near Stourbridge.	As bright as the half moon.	The train green, purple, and yellow.	6 seconds......	Shot from a point about 40° or 50° above the N.W. horizon towards and about halfway to the W. point of the horizon.
27	About 7 30 0	Tooting, near London.	Nearly = ♀	Brilliant white	More than 2 seconds.	From near the Sword-hand of Perseus to about 2° beyond ½ (α. β) Andromedæ.
27	7 35 0	Bristol	2nd mag.	....	....	Shot towards Venus from E. to W.
Apr. 19	10 42 30	Newcastle-on-Tyne.	1½ mag.	White	1·1 second ...	Passed 1° above, and disappeared about 5° beyond Spica.
19	10 44 0	York.............	1st mag.	Yellow	Less than 1·5 second.	From *d* Boötis to about 5° south of β Leonis.
19	11 15 0	Radcliffe Observatory, Oxford.	1st mag.	Bluish	1·5 second ...	From δ Draconis to γ Cephei.
19	11 17 0	Street, near Bath (Somersetshire).	1st mag.	Blue	1·5 second ...	$\alpha=$ $\delta=$ From 295° 44° to 307 55
20	10 22 15	Newcastle-on-Tyne.	1½ mag.	Orange-yellow	0·6 second ...	From θ Coronæ to ϵ Boötis (very exact position).

Length of Path.	Direction or Apparent Radiant-point.	Appearance; Remarks.	Observer.
....	....	Left sparks and smoke on its track. Position of apparent path carefully observed. A sound as of an explosion was heard 3 seconds after its disappearance.	E. B. Gardiner. Communicated by W. F. Denning.
....	Radiant R G	Left a streak	T. Crumplen.
Short course...	Towards Tarandus	Left no streak	Miss Herschel.
....	....	Illuminated the clouds brightly in the northern sky. [Seen also at Manchester as a large fireball; vivid blue, duration 10 seconds; moving from S.E. to N.W.]. (Detonating. See Appendix II.)	W. F. Denning.
[25°]	[E. to W.] Inclination about 40° to the horizon.	Nucleus with a long streak or train as wide as half the apparent diameter of the moon, and of mingled colours.	'Nature,' Feb. 6, 1873.
....	....	Left a streak for 2 seconds (?). Readily compared with Venus, which was only a few degrees off. Had two distinct maxima. The point of termination more correctly observed than the commencement.	H. W. Jackson.
....	....	Sky rather cloudy. Several bright meteors were visible this evening, without particular attention being paid to note them.	W. F. Denning.
20°	Directed from $\frac{1}{3}$ (δ, α) Serpentis	Lyraid. Left no streak	A. S. Herschel.
....	Radiant Vega Lyræ	Lyraïd. Left a bright streak lasting, with the meteor, $1\frac{1}{2}$ second.	A. K. Brown and T. H. Waller.
....	[From Cerberus]	Left a streak. [The agreement of this observation with that of the next meteor, both in time and in apparent position, is very doubtful and imperfect.]	J. Lucas.
2°	Lyraïd	Left a slight streak..................	J. E. Clark.
....	Lyraïd	Left a white streak for $\frac{1}{2}$ a second; brightest in the middle of its course.	A. S. Herschel.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1873.	h m s					
Apr. 20	10 23 0	Sunderland (Durham).	2nd mag.	....	....	Disappeared at $\alpha=213°$, $\delta=+35°$, or at $\frac{4}{3}$ (γ, A) Boötis.
20	11 7 0	Ibid...............	4th mag.	....	Rather quick...	Disappeared at $\frac{1}{2}$ (h Comæ Berenices, E Leonis).
20	11 7 0	Newcastle-on-Tyne.	4th mag.	White	0·8 second ...	Disappeared at ϵ Virginis. (Termination well observed).
20	11 15 15	Ibid...............	$3\frac{1}{2}$ mag.	Yellow	0·6 second ...	From η Virginis to 2° below e Leonis.
20	11 15 30	Sunderland (Durham).	2nd mag.	....	Quick	Commenced 2° above η Virginis.
Aug. 2	11 38 0	Radcliffe Observatory, Oxford.	1st mag.	White	1 second	From Polaris to σ Ursæ Majoris.
2	11 40 0	Bristol	= ♃	....	0·8 second ...	$\alpha=$ $\delta=$ From 43°+54° to 62 +56
7	9 33 0	Radcliffe Observatory, Oxford.	= ♀	Yellow	2 seconds......	Began at ϵ Ursæ Majoris and disappeared behind the observatory tower.
7	9 33 0	Bristol	2× ♀	....	0·9 second ...	$\alpha=$ $\delta=$ From 190°+59° to 195 +30
9	11 33 0	Regent's Park, London.	2nd mag.	Blue	....	$\alpha=$ $\delta=$ From 225°+66° to 223 +45°
9	11 34 0	Bristol	2nd mag.	....	0·6 second ...	From 51°·5+44°·5 to 57 +34
11	9 11 0	Tooting, near London.	1st mag.	White	....	$\alpha=$ $\delta=$ From 65°+81° to 70 +72 (Position accurately observed.)

Length of Path.	Direction or Apparent Radiant-point.	Appearance; Remarks.	Observer.
Not a long course.	Directed from ζ Coronæ towards $\frac{4}{5}$ (γ, A) Boötis.	A Lyraïd. Left a streak for a moment after the head vanished.	T. W. Backhouse.
....	Directed towards a point at about $\alpha=181°$, $\delta=+9°$.	[From a radiant north of Ursa Major.]	Id.
10°	Vertically down, as from Cor Caroli.	Left no streak. (Direction of path imperfectly observed).	A. S. Herschel.
10°	Directed from δ Virginis	Lyraïd	Id.
8° or 10°	Directed towards ϕ Leonis ...	Lyraïd. Nucleus undefined. Left a streak.	T. W. Backhouse.
....	....	....	J. Lucas.
12°	Pegasid	....	W. F. Denning.
	↙		
....	Its course prolonged onwards must have passed between α and η Boötis.	Left a streak	J. Lucas.
30°	Radiant Polaris [? or ϵ Cassiopeiæ].	Left a well-defined train just north of Cor Caroli for 7 seconds. [Seen also at Tooting, near London, "in the north going towards Richmond," *i. e.* westwards, and bursting out with sparks like a rocket, as it travelled. (Communicated by H. W. Jackson.)]	W. F. Denning.
....	....	....	T. Crumplen.
10°·5	Radiant χ Persei.................	Left a streak for a second	W. F. Denning.
	↓		
....	....	Left a bright streak. A beautiful explosion at the end of its course.	H. W. Jackson.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Magnitude, as per Stars &c.	Colour.	Duration.	Apparent Path.
1873.	h m s					
Aug. 11	9 11 0	Bristol	1st mag.	....	0·8 second ...	$\alpha=$ $\delta=$ From 11°+40° to 21 +29
11	9 12 0	Radcliffe Observatory, Oxford.	1st mag.	Yellow	2·5 seconds ...	From ζ Cassiopeiæ to 46 [ω] Andromedæ.

II. Large Meteors and Aerolites.

In the 'Monthly Notices of the Astronomical Society' of the past year (vol. xxxiii.), several interesting instances of very large meteors are recorded. The earliest having occurred nearly on the same date of the year as the well-known fall of the meteorite of Orgeuil (on the 14th of May, 1867), it may very possibly have been, as its description renders probable, an aërolitic fire-ball. It is thus described by Commander H. P. Knevitt, as observed on board of H. M. S. 'Fawn,' on the passage from Manzanilla to Panama. "On the 16th of May, 1872, at 2^h 45^m A.M. (the weather having been squally since midnight), a phenomenon was seen in the heavens at an altitude of about 50°, and bearing East of compass; the ship at the time being in lat. 14° 55′ N. and long. 99° 58′ W. I did not see it myself, but the following is the description given of it by Lieut. Cecil G. Horne, who was the officer of the watch. Attention was first drawn by a very bright flash, resembling a small flash of vivid lightning, but being much more solid and lasting four to five seconds; the passage of the luminous body was towards the horizon for a short distance (say 3° or 4°) in a zigzag course; it then appeared to burst and throw off a tail such as a comet has, the tail forming a ring and spreading itself round the body till the whole had very much the appearance of a large Catherine-wheel; it then gradually faded out of sight, having been visible from first to last about ten or fifteen *minutes*."

A large meteor observed at the Mauritius at about 7 o'clock P.M. on the 7th of November, 1872, by Mr. W. Wright, is described at p. 176 of the same volume, being communicated to the Astronomical Society by Mr. Meldrum. The appearance of the meteor was exactly like that of the moon in her first quarter, the lower quarter only of the disk being illuminated and the upper three quarters being of a dull dusky stone-brown colour. The writer's attention was drawn to it by a sudden flash above the brightness of moonlight; and it appeared to him to fall from the direction of Aquarius. In communicating this observation to 'Nature' of January 23rd, 1873, Mr. Meldrum remarks that the moon was actually at the end of her first quarter, in the position indicated by Mr. Wright as the direction in which he observed the meteor;

Length of Path.	Direction or Apparent Radiant-point.	Appearance; Remarks.	Observer.
13°	Radiant Andromeda .... 	[The real radiant of the meteor, by comparison of these observations, was near β Draconis.]	W. F. Denning.
....	Path curved thus— .... 	....	J. Lucas.

and his description of its appearance differing widely from that of any large fireball hitherto observed, it is questioned by Mr. Meldrum if the object which appeared to Mr. Wright may not have been the moon itself, flashing forth, perhaps suddenly from behind clouds, and by their motion appearing to descend among them. A similar meteor, Mr. Wright adds, was seen at the Mauritius about a year previously; but the entire disk of that meteor was luminous, and the moon, at the time when the meteor presented itself, was not shining.

The following description (on the same page of the above 'Notices') refers to the bright meteor of the 3rd of November, seen at Glasgow and elsewhere in Scotland at half-past five o'clock in the evening, which appears, from this account, to have been aërolitic or of a detonating kind. Mr. H. D. Penny writes thus from Nairn to Mr. Duncan:—" I was coming up the street at 5.30 P.M. on that day, when, without any warning, I seemed enveloped in flame; on looking to the sky it seemed illuminated, and continued so for two or three seconds, so brightly that I had no difficulty in seeing the smallest stone on the ground. For a second or so the illumination waned, and then it shone for a second brighter than before. I hurried home to see the exact time of the circumstance; and being about 100 yards or so from the house, I heard, on coming at the gate, a low rumbling noise as of distant thunder away to the south-west. I then concluded that it was thunder, and remained outside for half an hour in the expectation of hearing more, but in vain, as thunder is rather uncommon in this quarter at this season." On making inquiries respecting it, Mr. Penny found that other persons, a few miles from Nairn, more fortunate than himself, had observed the fireball itself; and the description given to him by one of them is as follows:—" He saw a large ball of fire, about the size of the full moon, coming up from the east-south-east, about twenty degrees from the horizon, and gliding along comparatively slowly, so that he could distinctly discern it. The ball was of the colour of intensely heated iron, and had a tail attached to it. For the two or three seconds that it remained in sight, the sky was so lighted up that he could have picked a pin from the ground. It then seemed to him to descend behind some of the hills to the south-west of him; and for a second the sky was darkened, when all at once the light burst forth stronger than before;

LARGE METEORS AND FIREBALLS OBSERVED

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1866. Jan. 1	h m s 9 20 0	Bristol	Brighter than the fixed stars.	...	...	Passed a few degrees from the moon, and near a certain bright fixed star, either Procyon or Pollux.
Nov. 13	9 18 30	York	2×♃	Yellow	3½ seconds	From clouds close to Mars to κ Fornacis (110°, +22°·5 to 34°, −24°·5). Low down along the eastern horizon.
13	12 30 0	Bristol	Far the brightest meteor seen during the November shower.	...	...	Passed directly across the zenith.
Dec. 10	10 24 0	Ibid.	Brighter than any meteor seen on November 13 to 14, 1866, excepting perhaps the above noted.	Blue	...	Commenced near the constellation Ursa Minor, and taking a southerly direction, disappeared when it reached Orion.
1868. Sep. 14 or 15	About 8 o'clock. (Exact time and date uncertain.)	Keynsham, near Bristol.	As bright as either of the foregoing meteors.	...	Glided along the sky.	Commenced near Cassiopeia. (Apparent path not exactly noted.)
1869. Aug. 11	14 8 0	Radcliffe Observatory, Oxford.	...	...	...	Position of the bright streak about midway between α Cygni and α Aquilæ.
Oct. 27	8 15 0	Besselsleigh, near Oxford.	= ♃	White	2 seconds or 3 seconds.	From ψ Tauri to the Pleiades.
Nov. 15	10 13 0	Radcliffe Observatory, Oxford.	= ♃	White	2 seconds	From Pollux to λ Ursæ Majoris.
19	7 0 0	Ibid.	= ♃	...	...	Passed through Ursa Major.
1870. Mar. 30	8 20 0	Ibid.	> ♃	Brilliant white	About 5 secs.	From the zenith to a point near the horizon, a little south of east.

CHIEFLY DURING THE YEARS 1872 AND 1873.

Length of Path.	Direction or Radiant-point.	Appearance; Remarks, &c.	Observer.
....	From west to east	A splendid meteor; very conspicuous, though passing so near the moon, which was very brilliant. Sky very clear after a cloudy evening.	W. F. Denning.
80°	From N.E. to S., in a horizontal, slightly curved course.	Left a bright green streak, gradually growing fainter. Apparently an early meteor of the stream of Leonids.	J. E. Clark, and several other observers.
.. ..	E. to W	Left a vast train of light; at first seen as a long streak, but soon becoming wavy or serpentine, and like a nebulous cloud, which grew fainter and drifted from its place until it disappeared, having been visible at least *three quarters of an hour.*	W. F. Denning.
[90°]	[N. to S.]	Illuminated the whole sky (which was at the time hazy, with a slight fog obscuring the fainter stars). Immediately before extinction, burst into many fragments like a rocket. Left no perceptible streak. No sound of an explosion heard.	Id.
....	....	Illuminated all surrounding objects with a sudden light; disappeared rather suddenly, left no streak.	Id.
....	The meteor must have started from, or passed near the zenith, and have disappeared behind trees in the west.	The observer was startled by a bright flash, and on looking in the direction named, saw the streak which remained upon the meteor's course. (Also described in the 'Astronomical Register' for September 1869.)	J. Lucas. (Radcliffe Observations, 1869.)
....	....	....	Id.
....	....	Left a faint streak	Id.
....	Downwards........................	....	Id.
....	Vertically downwards............	Disappeared behind some trees ..	J. R Main.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1870. Sep. 25	h m s 8 51 0	Radcliffe Observatory, Oxford.	> ♃	....	4 seconds......	From a point above γ Delphini to a point below α Aquilæ.
26	15 15 0	Ibid..............	= ♃	Blue	3 seconds......	From α Andromedæ to between α and γ Pegasi.
Oct. 1	About 8 0 0	Ibid..............	= ♃	White to blue	3 seconds......	From a little below β Ursæ Majoris; bursting at ψ Ursæ Majoris.
1871. Apr. 10	11 45 0	Ibid..............	= ♃	....	4 seconds......	From a point near ζ Herculis to α Coronæ.
Sept. 1	8 44 0	Ibid..............	6 × ♃	Green to orange.	5 seconds......	From a point near α Serpentis.
Nov. 13	11 25 15	Cambridge	Very large and bright.	....	....	Passed across β Cassiopeiæ.
Dec. 6	6 25 0	Radcliffe Observatory, Oxford.	= ♃	White	6 seconds......	Fell from a point west of Polaris to near the horizon.
1872. July 27	11 40 0 and 12 30 0	Dalston, near London.	The first meteor rather fainter than the second, which was a very bright fireball.	Red	....	The first fell in the north, the second more to the east, at some altitude in the sky.
29	About 9 30 0 (local time).	Creuznach (Germany).	Large shooting-star	....	....	Shot from ⅓, or ¼ ε Pegasi, α Cygni, straight towards Saturn, and nearly as far.
Aug. 18	10 45 0	Cambridge	Twice or thrice as bright as a 1st mag.*, and larger than Venus ever appears.	Brilliantly white.	Quite 5 secs. if not 10 seconds; remarkably slow speed.	From near Lyra to near Andromeda, where it disappeared behind buildings.
19	10 20 0	York	Large meteor	....	....	From 35° S. of E., altitude 30° to 30° S. of E., altitude 10°. (Position not very precise; by reference to the moon.)

Length of Path.	Direction or Radiant-point.	Appearance; Remarks, &c.	Observer.
....	....	....	J. Lucas.
....	....	On Sept. 28, at 7^h 25^m, a sudden flash of light, evidently meteoric, was observed, but no meteor could be traced. (See also the 'Astronomical Register' for Nov. 1870.)	Id.
....	....	....	Id.
....	....	....	Id.
....	Fell vertically downwards	....	Mr. Keating and J. Lucas.
....	Horizontally from right to left. ←	One of the brightest meteors hitherto observed. Among about 30 meteors mapped with a meteoroscope on the same night; not more than 8 or 9 had their radiant-point in Leo. [Also observed at Beckenham, Kent. See last Report.]	W. Davenport. Communicated by W. F. Denning.
....	Vertically downwards	....	J. Lucas and Mr. Keating.
....	....	The first meteor faint in colour; the second very bright, resembling a red-hot iron bolt or urn-heater.	Joseph Seaton. (Communicated by G. J. Symons.)
....	....	....	H. W. Jackson.
....	The opposite direction to that of the Perseids, or August meteors.	Pear-shaped with a narrow short train 1° or $1\frac{1}{2}$° long. Its brightness decreased, and its speed diminished towards the end of its course as if by the effect of foreshortening.	E. H. (newspaper paragraph). Communicated by R. P. Greg.
....	Probable direction:— ↓	Fireball; nucleus with a considerable disk. Well observed.	Communicated by J. E. Clark.

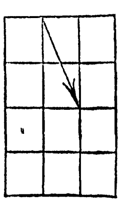
Date.	Hour, Approx. G. M. T.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1872. Sep. 17	h m s 7 50 0	Ticehurst (Sussex).	Very large fireball	....	About 10 secs.	Fell from S.W. to S.E.
22	8 54 0	Tooting, near London.	= α Lyræ; very bright.	....	Swift	Apparent course as in the sketch. Vega.  αOphiuchi.
Oct. 9	9 19 0	Glasgow	One tenth apparent size of the moon.	Yellow	0·75 second; very swift.	From ε to η Persei.
9	About 12 0 0	Hay, S. Wales...	About = ♀	Yellowish......	Slow motion...	Passed from near and a little *n. f.* ζ, towards β Ceti, disappearing a little before reaching that star.
27	A little before 12 0 0 (local midnight.)	Samoa, South Pacific.	Unusually large fireball.	....	....	It became visible near ζ Ceti, and rushed towards the south-east.
Nov. 1	About 11 50 0	Portsmouth ...	= ♀	White (?)......	½ second	α= δ= From 100°+48° to 132 +49
6	10 45 0	Ibid...............	= ♃	White	Very swift; 0·3 second.	From 77°+35° to 91 +47
17	6 10 0 p.m.	South Shields (Durham).	Brighter than ♀ ...	White	About 1¼ or 1½ second.	From a point about N.W., altitude 15° or 20° to a point about W.N.W., altitude 3° or 4°.
19	9 10 0	Bristol	Very bright meteor	....	....	Shot down the north-west sky.

Length of Path.	Direction or Radiant-point.	Appearance; Remarks, &c.	Observer.
....	....	The meteor did not burst, but began small and grew brighter and brighter until it went out. Just before disappearance it "appeared as large as a break-fast-plate."	Communicated by A. Eden.
....	....	Left no streak	H. W. Jackson.
20°	Shot upwards	Nucleus accompanied by sparks; disappeared with an explosion: left a white streak in passing over α and γ Persei, which remained visible fifteen seconds.	Robert M'Clure.
....	Path a little convex to the zenith.	For three fifths of its course it continued equally bright, a fireball with sparks round it, and a slight train. In the rest of its course it diminished gradually to disappearance.	T. W. Webb. ('Nature,' Oct. 17.)
....	....	Left a bright train in its wake. Nucleus of the meteor of very large apparent width. Several other bright shooting-stars were visible on the same night. [See this Appendix, below].	S. J. Whitmee. ('Nature,' Jan. 30th, 1873.)
....	....	The meteor appeared behind a cloud, through which it shone; and it must have been exceedingly bright.	G. L. Tupman.
15°	....	Nucleus accompanied by a slight train; left no streak.	Id.
About 25° ...	....	Meteor very bright when first seen, and remained so until it disappeared without bursting close to the horizon. Nucleus with short tail of red sparks; left a streak for a moment or two along its track.	F. Hurman and John Taylor.
....	....	The brightest meteor seen during the month. A flash of light, apparently meteoric, appeared at about 9^h p.m. on the 18th of November, when the sky was nearly overcast.	W. F. Denning.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1872. Nov. 22	h m s About 5 14 0	South Kensington, London.	Rather brighter than ♃ at his brightest.	....	....	Disappeared about 10° before reaching the zenith, which it would have gone about 5° or 10° to the south of.
23	7 20 0	Bristol	> ♀	Blue.........	About 2 secs..	$\alpha=$ $\delta=$ From 18°+44° to 164 +63 From the N.W. part of Andromeda, across the sword-hand of Perseus, and Camelopardus to the head of Ursa Maj.
30	8 10 0 (local time).	St. Thomas (West Indies).	Large meteor	....	....	....
Dec. 9	11 15 0	Tooting, near London.	A bright meteor ...	Deep red	Exceedingly slow speed; not less than 5 seconds or 10 seconds.	Shot on a line from β through π Pegasi to γ Cygni, beginning near π Pegasi and ending near γ Cygni.
23	6 10 0	London	Brighter than the fixed stars.	....	....	From close to Polaris, passed close to α, β Ursæ Majoris, through the square of Ursa Major.
26	7 58 0	Bristol	= ♀	Blue	2 seconds ...	From 343°+22° to 338 − 4
26	9 30 0	Ibid.........	About as bright as the quarter-moon.	Blue	....	First seen at altitude about 60° in the north-west.
1873. Feb. 3	10 0 0 p.m. (local time).	Australia.........	Very large	....	....	....
April 6	9 8 0	Ibid.........	Nearly as bright as Venus at her brightest.	....	About 1·5 second; motion slow.	$\alpha=$ $\delta=$ From 83°+42°·5 to 56 +31 Began between α, β, θ Aurigæ and ended near ζ Persei, about 10° above Venus.

Length of Path.	Direction or Radiant-point.	Appearance; Remarks, &c.	Observer.
....	N.E. to S.W.	A bright shooting-star. Estimation of position rougher than that of the time.	Mr. Merrifield. (Communicated by Dr. W. Huggins.)
....	....	Nucleus globular; faded and brightened again very rapidly several times. Illuminated the sky very strongly in its flight; left no streak, but emitted a spark in its course.	W. F. Denning.
....	E. to W.	....	Communicated by Mr. R. C. Rawson (Governor of Barbadoes). 'Nature,' Feb. 6th, 1873.
....	....	Nucleus with a short tail 2° or 3° in length, which distinctly tapered towards the end.	H. W. Jackson.
....	....	....	H. Hardcastle.
26°	Directed from a little north of β Pegasi downwards, almost perpendicularly.	The light of the nucleus faded and revived rapidly several times, like that of the meteor on Nov. 23rd. Left no streak.	W. F. Denning.
Long course..	E. to W.	Globular; no sparks or explosion, and it left no streak; but on a prolongation of its path, a small meteoric spark seemed to continue to some distance beyond its point of extinction.	F. Denning (and seen by several observers). Communicated by W. F. Denning.
....	....	On the same date and local time as the large meteor seen in England.—'Mechanics' Magazine,' May 2nd, 1873.	Communicated by W. H. Wood.
....	....	The nucleus did not explode, but disappeared gradually, and it left no streak.	W. F. Denning.

Date.	Hour, approx. G. M. T.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position.
1873.	h m s					
April 8	About 9 o'clock. ('Tuesday evening.')	Cardiff, S. Wales	Very brilliant meteor.	....	....	Shot across the sky from N. to S., and burst before reaching the horizon.
May 1	12 40 0	London	Brighter than any of the fixed stars.	Ruddy	....	Began not far from ζ Ursæ Majoris, and disappeared 15° below Polaris.
July 1	13 15 0	....	As bright as the full moon.	Blue...........	....	Appeared at a great elevation in the southern sky, passing from north-west to a low elevation in the south.
28	11 32 0	Bristol	= ♃	....	0·8 second ...	$\alpha=$ $\delta=$ From 210°+49° to 200+38
Aug. 2	10 28 0	Radcliffe Observatory, Oxford.	2×♃	Green	3 seconds......	Shot from Arcturus towards the N.W. horizon.
7	10 35 0	Grasmere, Cumberland.	= ♀ at her brightest	....	....	Disappeared at a point as far from γ Pegasi as α Andromedæ on a line drawn through γ Pegasi from $\frac{1}{2}$ α Andromedæ, β Pegasi.
7	12 11 0	Radcliffe Observatory, Oxford.	= ♃	White	0·5 second ...	From near 58 to near 63 Aurigæ.
9	9 10 0	Tooting, near London.	= ♃	Bright yellow	Nearly 2 secs..	....
11	11 30 0	Birmingham ...	= ♃	Vivid blue; like the magnesium flame.	3 seconds......	$\alpha=$ $\delta=$ From 339°−20° to 1 −20
16	11 27 30	Hawkhurst (Kent).	= ♃	....	1 second; very slow.	Passed close to and on the left of θ Piscium.
Sept. 9	10 5 0	Pontefract, Yorkshire.	Much brighter than ♀. A sensible apparent disk.	Yellow	0·75 second ...	From 37° south of east, altitude 49°, to 48° south of east, altitude 10°.

Length of Path.	Direction or Radiant-point.	Appearance; Remarks, &c.	Observer.
....	N. to S.	Burst like a rocket, the fragments illuminating a large area of the sky.	'The Western Telegraph,' Thursday, April 10th, 1873.
....	....	Nucleus pear-shaped with a long broad tail, and leaving a few sparks along its track.	T. Crumplen.
....	....	A magnificent fireball. Nucleus of very intense light, separated into two halves and afterwards into numerous pieces which immediately became extinct.	W. Bowman and other observers. (Communicated by W. F. Denning.)
14°	Fell vertically; radiant in Pegasus.	....	W. F. Denning.
....	Zigzag path............	Left a streak	J. Lucas.
....	Directed from γ Andromedæ, and from $\frac{1}{2}$ (γ, η) Persei.	Left a streak. Imperfect view of its course among clouds, behind some of which it may possibly have disappeared.	T. W. Backhouse.
....	....	[A bright meteor on the same evening at 9^h 33^m. See the foregoing list.]	J. Lucas.
....	....	A very beautiful meteor; left a faint streak.	H. W. Jackson.
....	Radiant O_1 (Neumayer)............	Left a streak. Nucleus very bright; appeared occasionally through the clouds (between which the moon shone) as if below them. Nearly approached the horizon; disappeared with an explosion.	W. H. Wood.
4°............	Directed from $\frac{1}{3}$ (ϵ, η) Pegasi...	....	Miss Herschel.
....	Inclined about 70° to a vertical direction, thus:— 	Seen through the window of a well-lighted room. The view of the beginning and end were perhaps intercepted, and no streak was certainly perceptible.	E. Worsdell. Communicated by J. E. Clark.

and shortly afterwards he heard a sound as distinctly as if three or four cannon had been at once discharged at a distance of a quarter of a mile. But the last lighting up of the sky seemed only for an instant, when all was as dark as before. . . . . There must have been a meteor of extraordinary size travelling from the southern part of Banffshire on towards the centre of Inverness-shire, and bursting somewhere near the source of the river Nairn. The brilliancy of the light was as if a brilliant flash of lightning had remained visible in the sky."

Aërolites.—The following extract from a journal of travels in North-west America, 'The great Lone Land,' by Capt. W. F. Butler, F.R.G.S. (1872), deserves attention, as the existence of the mass of meteoric iron which it describes appears to have been hitherto unknown, or unrecorded.

"In the mission-house of Victoria (on the Saskatchewan river, not far from its source) there lay a curious block of metal of immense weight; it was rugged, deeply indented, and polished on the outer edges of the indentations by the wear and friction of many years. Its history was a curious one. Longer than any man could say, it had lain on the summit of a hill far out in the southern prairies. It had been a medicine-stone of surpassing virtue among the Indians over a vast territory. No tribe or portion of a tribe would pass in the vicinity without paying a visit to this great medicine: it was said to be increasing yearly in weight. Old men remembered having heard old men say, they had once lifted it easily from the ground. Now no single man could carry it; and it was no wonder that this metallic stone should be a 'Manito'-stone, and an object of intense veneration to the Indian; it had come down from heaven; it did not belong to the earth, but had descended out of the sky; it was in fact an aërolite. Not very long before my visit, this curious stone had been removed from the hill upon which it had so long rested, and brought to the mission of Victoria by some person from that place. When the Indians found that it had been taken away, they were loud in the expression of their regret. The old medicine-men declared that its removal would lead to great misfortunes, and that war, disease, and dearth of buffalo would affect the tribes of the Saskatchewan. This was not a prophecy made after the occurrence of the plague of small-pox; for in a magazine published by the Wesleyan Society in Canada there appears a letter from the missionary setting forth the prediction of the medicine-men a year prior to my visit. The letter concludes with an expression of thanks that their evil prognostications had not been attended with success. But a few months later brought all the three evils upon the Indians; and never, probably, since the first trader had reached the country, had so many afflictions of war, famine, and plague fallen upon the Crees and Blackfeet as during the year which succeeded the useless removal of their Manito-stone from the lone hill-top upon which the skies had cast it."

Siderite of Augusta County, United States (see 'American Journal of Science' for July, 1872).—Analysis of the gases occluded in the iron, by Dr. J. W. Mallet, U.S. ('Proceedings of the Royal Society,' vol. xx. p. 365). Both shavings and a small bar of the iron cut and polished cold, and freed from oil, from the most solid part of the iron were heated first to redness and then to whiteness in the vacuum of a Sprengel pump. The experiment lasted $14\frac{1}{2}$ hours, only a quarter of the whole volume of gas being extracted in the last two thirds of the time, and a small residue still remaining unextracted at its close. The quantity of hydrogen and carbonic acid diminished most rapidly; and those of nitrogen and carbonic oxide continued to be discharged most abundantly towards the end of the time, as the following Table of the

percentage volumes shows, which were obtained from 15·87 cubic centims. of the iron in successive intervals of—

	$2\frac{1}{2}$ hours. per cent.	$2\frac{1}{2}$ hours. per cent.	$9\frac{3}{4}$ hours. per cent.	Total. per cent.	Horseshoe-nail (Grahame).
Hydrogen	22·12	10·52	3·19	35·83	35·0
Carbonic oxide	15·99	11·12	11·22	38·33	50·3
Carbonic acid	7·85	1·02	0·88	9·75	7·7
Nitrogen	6·06	1·45	8·58	16·09	7·0
	52·02	24·11	23·87	100·00	100·0

Reduced to the standard temperature, 60° F., and barometric pressure, 30 inches, the whole volume obtained was 50·40 cubic centims., or 3·17 times the volume of the iron, while Grahame found 2·85 times its volume of mixed gases occluded in the Lenarto iron. The quantity of hydrogen contained in the Augusta-County iron is 1·4 times its volume, while ordinary terrestrial iron only occludes about 0·42 or 0·46 times its volume; and the meteoric origin of the mass is thus confirmed. But the quantities of carbonic oxide and carbonic acid, especially, are much larger than the corresponding quantities found by Grahame in the Lenarto iron, and more nearly resemble the proportions found in a sample of a horseshoe nail. It cannot be supposed that the Augusta-County iron has undergone any artificial process to test or to improve its quality; and hence it may be inferred that the atmosphere in which it originated as a meteorite was more rich in carbon than that from which the Lenarto iron was derived.

Siderite of Ovifak, Greenland.—Among the discoveries made by Sir J. C. Ross in his Arctic voyages, was that of some implements partly made of iron by the Esquimaux of Greenland, the metal of which was found on analysis to be probably of meteoric origin. The iron used in their manufacture was reported by the Esquimaux to exist on the shore of Cape York, some hundreds of miles north of Disco Island, on the west coast of Greenland. During his investigations of that coast in the year 1870, Prof. A. E. Nordenskiöld, of Stockholm, by offering rewards for its discovery to the Esquimaux, learned the existence of such masses of native iron at Ovifak, on the south side of Disco Isle. Arrived at this indicated spot, Prof. Nordenskiöld was there shown the largest piece of meteoric iron yet known to have been found. Two other large, and many smaller fragments lay at no great distances from it. Their site was between high- and low-water mark on the shore, among sea-worn blocks of gneiss and granite at the foot of a high rock of basalt. A Swedish vessel transported them to Europe; and they are now deposited in the Royal Museum at Stockholm. The largest one weighs about 50,000 lbs., and the two smaller masses about 20,000 lbs. and 9000 lbs.; the rest of the fragments together weigh about 1500 lbs. Nickel, cobalt, phosphorus, and sulphur enter into their composition; and the probability of their meteoric origin is ably maintained by Nordenskiöld in his narrative of this expedition ("Redogörelse för en Expedition till Grönland." Stockholm: 1871), and in a later work on the history of the iron. Not many yards from the place of their discovery a siliceous stone, enclosing grains and lumps of metallic iron, and a vein of that metal some feet in length and a few inches thick, projected from the basalt breccia of the locality, and differed in its trap-like composition entirely from the stones among which it lay. A portion of this iron, together with specimens of the larger blocks, was presented to Dr. F. Wöhler for

analysis, who found in its chemical composition the following approximate ingredients :—

Fe	Ni	Co	Fe_3O_4	FeS	C	P	Total.
46·60	1·19	0·47	40·20	7·75	3·69	0·15	100·05

On heating the iron strongly *in vacuo*, carbonic oxide and carbonic acid gas are given off by the reaction of the free carbon on the magnetic iron oxide with which it is in contact; and the amount of oxygen present in the iron is so great (11·09 of its weight of oxygen being extracted from it when heated in hydrogen gas), that no lower oxide of iron than that here assumed can be regarded as its original mode of combination. As octahedra of magnetic oxide were found by Nordenskiöld in the larger siderites, the highly siliceous stone appears to be of the same origin as the large iron masses; and the admixture of free carbon and magnetic oxide of iron in its composition appears to indicate that it has never been exposed to a very high temperature, since its deposition in its present site. (F. Wohler's Analysis of the Ovifak meteoric iron, Poggendorff's 'Annalen,' July 1872).

Montlivault, Loir-et-Cher, France, 1838, July 22.—This and the following meteorite have lately been added by M. Daubrée to the collection in the Geological Museum of the Jardin des Plantes at Paris. The meteorite weighs 510 grammes; it has the form of a three-sided pyramid. Its material is a finely granular mineral, consisting chiefly of olivine and augite with grains of nickeliferous iron and magnetic pyrites belonging to the aërolitic group to which the name of leucite has been given. ('The Academy,' May 15th, 1873.)

Beuste, Basses-Pyrenées, France, 1859, May.—Two pieces of the stone were found 700 metres apart, the larger weighing 1·4 kilogramme, and the lesser one 420 grammes. The smaller stone penetrated the ground to the depth of half a metre; it is covered with a black crust half a millimetre thick; and its specific gravity is 3·53. It belongs to the Chantonnite group, and most nearly resembles the meteorites of Poultousk. Its grey compact mass is penetrated in every direction by veins of a black mineral, which anastomose and exhibit irregular ramifications. (*Ibid.*)

Shergotty, India, 1865, August 25, 9 A.M. (local time).—This stone was recently analyzed and examined by Prof. Tschermak ('Jahrbuch für Mineralogie,' 1872, No. 7). The chief mass of the stone is a greyish brown augitic-looking mineral, of which, however, the following analysis shows that it does not possess the true augitic composition :—

Silica.	Alumina.	Iron protoxide.	Magnesia.	Lime.	Total.
52·3	0·2	23·1	14·2	10·4	100·2

Another mineral having the percentage composition

Silica.	Alumina.	Lime.	Soda.	Potash.	Total.
56·3	25·7	11·6	5·1	1·3	100·0

forms small octahedral crystals with vitreous fracture in the mass; and having not been observed so definitely hitherto, it has received the name of *Maskelynite* as a new species. Bronzite, magnetic oxide, and sulphide of iron form the remaining ingredients of the stone, whose mineral and chemical characters strongly resemble those of the meteorites of Stannern, Juvenas, Jonzac, and Petersburg, these stones as a class forming a group that is widely separated from the great majority of ordinary aërolites. (*Ibid.*)

Ibbenbühren, Germany, 1870, June 17, 2 P.M. (local time).—In the same No. of Poggendorff's 'Annalen' as that last cited (of July 1872) is contained the analysis by Dr. G. vom Rath, and the microscopic examination of thin sections by Dr. O. Büchner, of a meteorite which fell in Westphalia in June 1870. The principal meteorite, weighing $2\frac{1}{2}$ lbs., struck the earth some distance from a countryman who heard it fall, and, when passing by the same place two days afterwards, observed the hole where it had penetrated the earth of a well-trodden footpath to a depth of $2\frac{1}{2}$ feet. It was almost uninjured, being covered, except at some corners, by the usual black crust. It was brought, several months after its discovery, to Dr. Heis at Münster, by whom some of the particulars attending its fall are related. A lightning-like flash, followed in about one minute by thunder, preceded the fall of the stone, which was heard striking the earth about three minutes after the flash. A small fragment, weighing about 1 oz., was found 300 or 400 paces from the larger stone; and no other fragments (the ground having since been tilled) could be afterwards discovered. The black crust is dull and extremely thin, its rippled texture and penetration into fine crevices of the stone being only discernible by means of a magnifying lens. As seen at the fractures, the interior mass is greyish white, compact, and contains no grains of metallic iron (which, with chrome-iron, are absent in this meteorite), but interspersed yellowish crystalline grains, generally minute, but at one of the exposed surfaces reaching to $\frac{1}{4}$ inch, and even to 1 inch in diameter. The microscopic sections show that this structure is continuous, the whole mass being composed of the same crystalline ingredients in larger or smaller grains. The specific gravity of the grains is about 3·425, and that of the matrix about 3·405. Chemical analysis also leads to the same conclusion, the separate crystals being found to have the composition—

	Silica.	Iron protoxide.	Magnesia.	Oxides of manganese and calcium.	Alumina.	Total.
	54·51	17·53	26·43	1·33	1·26	101·06
Oxygen	29·07		14·82		0·59	

which is also the composition of the matrix. Classing the manganese with the iron, and the calcium oxide with the magnesia, the mineral substance is a bronzite, or enstatite (RO, Si O_2), in which the atomic proportion of iron oxide to magnesia is as 4 : 11. This simple composition is almost unique among meteorites; but the aërolite of Shalka (India, November 30th, 1850), as analyzed by G. Rose and Rammelsberg, consists mainly of a bronzite (86·43 per cent., together with olivine 10·92, and chrome-iron 2·11 per cent.), having almost identically the same composition, viz.:—

Silica.	Iron protoxide.	Magnesia.	Calcium oxide.	Sodium oxide.	Total.
55·55	16·53	27·73	0·09	0·92	100·82

The single-silicate composition of the Ibbenbühren meteorite occurs again remarkably in the nearly pure bronzite or enstatite materials of the aërolite of Menegaum (India, June 29, 1843), as determined by Rammelsberg and Maskelyne, the analysis of the crystalline portion of which (as given by Maskelyne), from which that of the matrix scarcely differs, was as follows:—

Silica.	Iron protoxide.	Magnesia.	Calcium oxide.	Total.
55·70	20·54	22·80	1·32	100·36

differing only slightly in its specific gravity (3·198), and in a rather higher

atomic proportion of iron-oxide to magnesia, from that of the foregoing minerals. No examples of terrestrial enstatites present nearly such a high percentage of iron in their composition as the above specimens of the same mineral found in meteorites are shown to exhibit by their chemical analysis.

Lancé, and Pont Loisel, Loir-et-Cher, France, 1872, July 23rd, $5^h 20^m$ P.M. (Tours time).—"A brilliant meteor passed over a spectator stationed between Champigny and Brisay, towards north-east, in the direction of Tours. It presented the appearance of a spear of flame with two spheres of fire of an orange colour. The track of one seemed to incline downwards, that of the other to proceed straightforwards, the whole appearance becoming somewhat more luminous at the instant that a slight divergence of the course of these two spheres was first seen. It was lost to sight behind a cloud at St. Maure, and an explosion was heard at $5^h 26^m$. Many observers affirm that they heard two distinct explosions very near together; others noticed but one; all testify to the appearance of two meteors pursuing nearly the same path. A meteorite fell in a field near Lancé, Canton of St. Arnaud, and passed a metre and a half through the light soil into a bed of marl. It weighed 47 kilogrammes [104 lbs.]. Some fragments separated by the fall were found near it." (Note by M. de Tastes, presented by M. Ste-Clair Deville, 'Comptes Rendus,' July 29th, 1872.)

"In the last No. of 'Comptes Rendus' [August 5th, 1872] M. Daubrée records the more recent discovery of a second meteorite at Pont Loisel, 12 kilometres [$7\frac{1}{2}$ miles] south-east of Lancé. The line joining the two localities coincides with the direction of the trajectory of the meteors; and the Pont-Loisel stone, though much smaller (it weighs 250 grammes [about $\frac{1}{2}$ lb.]) bears the closest resemblance as regards mineral characters to the Lancé stone. The smaller stone fell first [i. e. *behind* the larger one]—a circumstance observed in former showers—and penetrated the soil to a depth of only half a metre [about $1\frac{1}{2}$ foot]." (Extract from 'The Academy,' September 1st, 1872.)

As a phenomenon perhaps connected with the appearance of the Lancé aërolite, it may be added that a large bolide (as described by M. W. de Fonvielle, in the 'Revue des Courses Scientifiques' of Aug. 3rd, 1867) was visible at Bayonne on the evening of the 23rd of July in that year; but no further particulars of its appearance and of its apparent course were stated.

Orvinio, Italy, 1872, August 31st, $5^h 15^m$ A.M. (Rome time).—In the 'Comptes Rendus' of October 1872, the occurrences of some bright meteors in August last are thus described by Father Secchi. One of these appeared on the 11th, and was visible at Rome, Velletri, Naples, and Palermo. A more remarkable one was seen at Rome on the morning of the 31st, at $5^h 15^m$ A.M., as a bright reddish fireball appearing near the S.S.W. horizon, and disappearing in the E.N.E. It moved slowly at first and then rapidly, expanding as it advanced to the form of a cone with a rounded base, and flaring up at disappearance with the emission of several bright lines, which were not seen by all the observers. A train of light like smoke remained upon its course, which shone as if illuminated by the sun's rays, although the sun had not yet risen. The sound of a violent explosion was heard a few minutes later which shook the windows of the houses. This was more like the dull heavy sound of the explosion of a powder-magazine than like thunder; and it was followed by a rumbling sound like that of distant musketry. Father Secchi heard the noise, but did not see the meteor. It was, however, also seen at Viterbo and Veroli; and the explosion was there heard quite as loud as at Rome. A farmer watching his fields near Porto d'Anzio, saw the meteor at first over

the sea apparently motionless, and at a quarter past five he perceived it again in another place. A shepherd near Subiaco narrowly escaped being struck by a fragment of the meteor, which proved to be aërolitic. Father Secchi regards the occurrence of this meteor as one of the most interesting appearances of the kind on record. [Several other stones fell, weighing from less than an ounce to one or two pounds, and the largest were found near Orvinio, about thirty miles E.N.E. from Rome. Smaller pieces were picked up at La Scarpa and Gerano, eight and fifteen miles south of the former place. See Poggendorff's 'Annals,' vol. cl. p. 171; November 1873.]

III. Meteoric Showers.

Italian Observations.—1838, June 23rd.—The No. for June 1869 of the 'Bullettino Meteorologico' of Urbino contains the following citation by Prof. Serpieri of a passage of the scientific works of Count Joseph Mamiani (Florence, 1845), where he describes, in six letters to Arago, the meteorology of Pesaro. "A few minutes before the occurrence (about 9 P.M.) of a very violent earthquake in that part of Italy on the 23rd of June, 1838, many shooting or falling stars were seen coming from the east; and they disappeared, gliding with their accustomed swiftness towards the south. They were pretty bright, of large volume, and appeared in such unusual numbers that people in Pesaro asked each other if fireworks were being discharged in some part of the town." Additional observations of this shower, or of its returns, if they can be traced, will be of great interest and importance.

1871, August 9–11th.—As seen at most of the Italian stations, it was observed that the frequency of the meteors in this annual return of the August shower was nearly equally great on the nights of the 10th and 11th, and the time of the maximum abundance was variously estimated as having been shortly before, or at some time after, sunrise on the morning of the 11th of August. Thus, at Cosenza Signor Bassani (assisted on the first night by Signor Scrivani) counted the following numbers of meteors in the half hours ending at

	9^h P.M.	$9\frac{1}{2}^h$	10^h	$10\frac{1}{2}^h$	11^h	$11\frac{1}{2}^h$	12^h	$12\frac{1}{2}^h$	13^h	$13\frac{1}{2}^h$	14^h	$14\frac{1}{2}^h$	15^h	$15\frac{1}{2}^h$	16^h	Total.
Meteors seen August 10th (2 observers)	18	33	34	28	49	58	43	58	59	57	57	32	44	46	58	674
Meteors seen August 11th (1 observer)	17	10	15	15	23	11	25	23	24	24	18	22	16	...	...	243

If the numbers seen in the first night are halved (having been reckoned by two observers), it will be seen that they were scarcely less abundant on the second than on the first night of the shower. The numbers seen at other places on the night of the 9th of August were much less than those counted on the nights of the 10th and 11th. A large number of the meteors seen were very bright, many descriptions of considerable fireballs occurring in the long accounts of this August star-shower collected in Padre Denza's 'Bullettino Meteorologico' of the Moncalieri Observatory for August to November, 1871, from which these notes of the star-shower are extracted. From the above list of observed hourly numbers, Signor Bassani concludes that the hour of maximum abundance of the meteors at Cosenza was during daytime, at about $10^h\ 34^m$ A.M. (local time) on the forenoon of the 11th. Padre Secchi at Rome and Prof. Galli at Velletri also consider it to have taken place

during daytime of the 11th; and by comparing together all the descriptions, Padre Denza regarded it as occurring between 2^h and 3^h A.M. on the 11th, irrespective of the effect of the rising moon in greatly diminishing the number of the meteors visible after that hour. A peculiarity of many of the brightest meteors was observed that they disappeared, and then again reappeared further on upon their course. The number of sporadic meteors was also greater than usual, being about one third of the whole number seen at Velletri in place of one fourth part, as was recorded in August 1869. The horary numbers of the shower at Velletri on the 11th of August, 1871, were greater than on the corresponding night (with an equally clear sky) in the year 1869, in the proportion of 102·2 to 67·5. The reduction of all the observations made for the determination of the radiant-point is being undertaken by Prof. Schiaparelli, to whom all the observations were forwarded, at Milan.

The November Shower in 1871.—In the same journal of Italian observations for December 1871 and January 1873, a few notices of observations of the November shower in 1871 at Italian stations are described. The sky was in general overcast, or nearly so, and few extensive watches could be kept. It was, however, found in Italy, as in England in that year, that the number of meteors from Leo seen on the nights of the 12th and 13th scarcely exceeded that of the unconformable meteors seen on the same nights. The time of central passage of the earth through the stream on the morning of the 15th (see the last volume of these Reports, p. 96) appears to have escaped observation at the Italian stations, the sky on that morning having been everywhere overcast.

Meteor-shower of August 7th–12th, 1872.—Observations of this shower were communicated to the Committee from most of the observers usually recording their notes of such phenomena for the British Association, by the staff of Mr. Glaisher's observers at the Royal Observatory, Greenwich, and by Professor Main's assistants at the Radcliffe Observatory at Oxford. The sky was completely overcast, with wind and heavy rain, on the night of the 9th of August; but with exception of this interruption a long list of observations of the shower was recorded on the other nights of its duration. The accompanying Table shows that the apparent paths of 447 meteors were mapped, of which nearly the same numbers were seen on the nights of the 10th and 11th by about the same numbers of observers watching for nearly the same time, in equally favourable conditions of the sky. Many of the shooting-stars were very bright, but the shower was not so conspicuous in the number of bolides, and of other meteors of all descriptions, as it was in the previous year. About twenty-five of the meteors seen were doubly or triply recorded by observers at distant stations, enabling their real paths to be computed, and a list of these simultaneous observations will be found in the foregoing catalogue of such results. The whole of the recorded tracks have been more or less completely projected upon graphic charts; but it has not yet been found possible to determine very clearly the predominating centre of emanation, or the general limits of radiation of the shower from the miscellaneous groups of evidence which so many valuable independent observations will in the sequel afford. For this purpose a thorough sorting of all the recorded tracks among the known radiant-points of the epoch will be required, for which sufficient time has not yet been at the disposal of the Committee.

Meteor-showers of September–November, 1872.—On the nights of the 5th to 9th of September, 1872, Mr. Clark recorded the paths of several shooting-stars at York, radiating chiefly from Cygnus and Andromeda, the greatest number mapped being ten per hour on the night of September 8th.

The sky was almost everywhere overcast on the nights of the 18th to 20th of October, 1872, and the moon shone brightly, so that no useful observations of the October meteors on this occasion of their annual return could be obtained. The condition of the sky was equally unfavourable on the annual date of the November shower of Leonids; and among the few meteors seen in this interval, the small groups noted by Mr. Backhouse at Sunderland on the night of the 30th of October, and by Captain Tupman at Portsmouth on the night of the 1st of November*, are the only indications reported to the Committee of meteors during the months of September to November having been more than ordinarily abundant on any night before the appearance in the latter month of the bright display of shooting-stars connected with the recent periodic approach of Biela's comet to the earth.

The instructions communicated by the Committee to the observers of these meteoric showers included directions to record any unusual abundance of meteors observable during the last week from the 23rd to 30th of November, and to note their radiant-point. The anticipated watch was regarded by all the observers with attentive interest; and the first symptoms of an approaching frequency of meteors was reported by Mr. Jackson of Tooting (Surrey), who, observing at Hyde Park in London on the evening of the 24th of November, in four 10^{m} intervals between $7^{h}\ 30^{m}$ and $9^{h}\ 15^{m}$ P.M., saw four meteors as bright as first-magnitude stars, all diverging from the expected direction of the Andromedes or Biela's comet-meteors. Between $11^{h}\ 20^{m}$ and $12^{h}\ 40^{m}$ on the night of the 26th of November, the sky being equally clear and starlight, no shooting-star was visible in an equally attentive watch.

The occurrence of a distinct shower of the Andromedes on the night of the 24th of November, 1872, was well proved by the observations of them obtained in America ('American Journal of Science,' 3rd ser. vol. v. p. 53, Jan. 1873). They were first seen by Mr. T. Hadley, Prof. Twining, and Prof. Newton at Newhaven between half-past seven o'clock and midnight on that night, when their number was about forty per hour for one observer. Several of their tracks were mapped, and the position of their radiant-point was estimated by Prof. Newton, at the time, as being two or three degrees north of the star γ Andromedæ†. They were also noticed by Mr. Gummere, of Bethlehem, Pa., on the same night. On the night of the 25th the sky was more obscured by clouds; but in comparison with the unconformable meteors visible at the same time, the frequency of the Andromedes appeared to be scarcely more than a third of what it had been on the previous night. During the night of the 26th the sky was quite overcast.

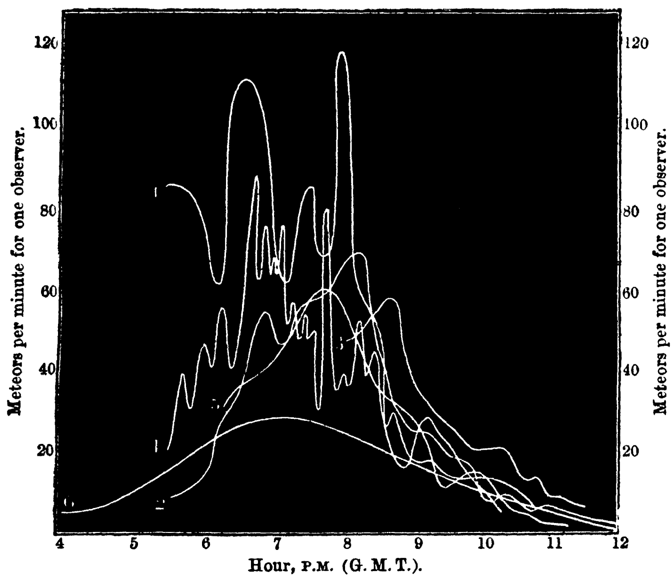
A correspondent of 'The Field' newspaper of January 25th, 1873, Mr. E. L. Layard, adds at the end of an animated description of the Biela comet-shower, as observed in his vicinity at Parà in Brazil, "on the night of the 26th of November [*i. e.* the 27th, European style] one of my servants informs me she saw an equally fine display on the 23rd inst." This notice of the earlier shower in South America evidently relates to the same border-stream of the Andromedes, observed also by Mr. Maxwell Hall ('Nature',

* As described in Appendix I. (Meteors doubly observed, November 3rd, 1872), viz. three radiant-points by Mr. Backhouse on October 30th, at 0°, +55° (4 meteors); at γ, λ Ceti (about 40°, +6°, eight or ten meteors); and perhaps a third radiant-point at ϵ Piscium of a few meteors not conformable to the two former points: and lastly a distinct radiant-point of ten pretty bright meteors seen in about 40 minutes on the night of November 1st, and of three others seen in about the same time on the night of November 3rd, at 56°, +24°, notified to the Committee by Captain Tupman.

† A radiant-point of some fainter and more rapid meteors was at the same time noticed in the eastern sky, perhaps in the neighbourhood of Orion.

March 6th, 1873) in Jamaica, with about the same radiant-point on the night of the 24th. The display of the 27th, Mr. Hall relates was simply a repetition of a star-shower quite similar to it on the former date.

The first announcement of the principal display on the night of the 27th of November was received by Prof. Herschel at Newcastle-on-Tyne, by telegraph, from Messrs. Waller and S. P. Thomson at York, and Mr. Backhouse at Sunderland at about 6 o'clock P.M., when it was also being watched at most of the observatories and other points of observation in the north of England and Scotland, while an impenetrable veil of cloud unfortunately prevented all the observers, south of a line drawn from Wisbeach on the Wash, through Birmingham, from obtaining a momentary view of it in the south of England. The best series of observations were accordingly only obtained at a few northern stations, where the sky continued cloudless throughout the night; and the rate of frequency of the meteors was thus counted continuously until the end of the display by Mr. Lowe at Beeston, near Nottingham, and by Prof. Grant at the observatory at Glasgow. During



the latter part of the shower a continuous enumeration of the meteors was also obtained by Lord Rosse at his observatory at Birr Castle in Ireland. The numbers counted by other observers in general only applied to very limited portions of the shower. It was thus observed by Captain Brinkley and his two sons, near Dublin, that bright meteors were already visible in full daylight on the afternoon, and that about twenty-three per minute could be counted by one observer as soon as dusk set in on the evening of the 27th, at about 5^h 20^m P.M. Counting alone, Mr. Lowe reckoned that an even greater number per minute could be counted by one observer at that early hour. The numbers, however, rose as the hour grew later; and between about half-past six and eight o'clock P.M. the shower continued to be visible at its greatest brightness, declining gradually after this time until an observer near Dublin, Mr. M. H. Close, looking out for more than a quarter of an

hour immediately after 2 o'clock A.M., with a sky fairly clear for observations saw not a single meteor in that time. By examining the accompanying diagram, it will be seen that the curves of meteoric frequency, 1, 2, 3, which represent the rates of appearance of the meteors observed by Mr. Lowe, Prof. Grant, and Lord Rosse, all descend towards midnight to the low average of about five meteors per minute for one observer.

At about the latter hour (corresponding to 6^h 52^m P.M., Washington mean time) the shower first began to be visible in the United States of America, where it was carefully observed by the astronomers at Washington, by Profs. Newton and Twining at Newhaven, by Mr. Marsh at Philadelphia, and by many other observers for some hours, with a view scarcely obscured by clouds. The following rates of appearance for a single observer are derived (as nearly as such reductions can be made by the convenient table supplied for this purpose by Prof. Newton; see these Reports for 1867, p. 412) from the numbers counted by the party of observers at Newhaven, and by Mr. Marsh at Philadelphia; and the correspondence, if not complete, yet shows that the rate of appearance of the meteors at the commencement of the shower in the United States of America, did not differ very greatly from that observed nearly at the same absolute time in England, when the most long-enduring series of observations there of their decreasing frequency towards midnight were discontinued.

Approximate numbers of meteors per minute for one observer of the star-shower in the United States of America on the 27th of November, 1872*.

Newhaven.

Washington mean time	$6^h 44^m$	54^m	$7^h 4^m$	15^m	28^m	42^m	58^m	$8^h 17^m$	38^m
Meteors counted per minute...	8·2	7·7	5·1	4·5	4·4	3·7	3·7	3·1	2·5
Greenwich mean time	$11^h 52^m$	$12^h 2^m$	12^m	23^m	36^m	50^m	$13^h 6^m$	25^m	46^m

Philadelphia.

Washington mean time	$6^h 16^m$	$6^h 23^m$	37^m	$7^h 20^m$	54^m	$11^h 37^m$
Meteors counted per minute...	5·5	3	2·5	2	1·5	0·2
Greenwich mean time	$11^h 24^m$	$11^h 31^m$	45^m	$12^h 28^m$	$13^h 2^m$	$16^h 45^m$

During the height of the shower various maxima occurred, the principal of which were seen by the English observers shortly before 7, and shortly after 8 o'clock P.M., with a less marked maximum between them. The greatest disagreement and uncertainties of the observations relate to the commencement of the shower, which set in and was first begun to be counted during the departing twilight. But as the sun had set nearly three quarters of an hour in Italy, and about an hour and a half at Athens when it disappeared in England, the observations begun at dusk in those more eastern stations supply materials to complete the curve of frequency towards its commencement, which may be more fully relied upon than the imperfect observations made at the same time in Great Britain. In the accompanying diagram, the curves 4 and 5 represent the numbers of meteors per minute for one observer, as recorded in Italy by Padre Denza at the observatory of

* The times of observation in the first list are the middle points of the periods in which 200 meteors were counted at Newhaven; and the numbers of meteors "per minute" are the average rates of frequency in those periods from the numbers counted in the separate intervals as stated in the original list, reduced in each case to the number that would have been recorded by a single observer watching for the same interval of time. The numbers in the second list are similar average rates for the middle points of the intervals of his watch, as obtained directly from Mr. Marsh's observations.

Moncalieri near Turin, and by Prof. Carlo Bruno at that of Mondovi in Piedmont. The curve No. 6 is the average rate of frequency per minute, as given for each hour of Athens time, beginning from about 4 o'clock P.M. (G.M.T), in the results of his observations of thé shower by Dr. J. F. Schmidt, the director of the Athens observatory. All the curves thus shown are drawn in the figure in their proper relative positions in Greenwich time.

The progress of the meteoric shower was intermittent, or composed of alternate lulls and outbursts of the intensity of the display which almost defeated attempts to count the meteors when flights of large numbers of them often appeared almost simultaneously. The mode of counting adopted by Professor Grant at Glasgow, and by Professor C. Bruno at Mondovi, of noting the numbers visible in successive intervals of 5 minutes, fails to show the rapid oscillations of intensity which took place, while it gives very distinctly the gradual variations of the shower. The method adopted by Padre Denza at Moncalieri was to record the minute and second of time at the end of each interval in which 400 meteors were counted, and the curve of frequency thus obtained shows all the sudden oscillations of the shower*. The description of its appearance by Padre Denza suggests that in the clear Italian sky more remarkable features attended it than have been recorded in any other meteoric shower. "Frequently small white or yellowish clouds sprang up in the clear sky, and after remaining visible for a few seconds disappeared. Some of these as soon as they appeared dispersed themselves in shooting-stars, in general minute, but sometimes all of considerable brightness, radiating towards every side like fragments from a bursting shell. The most remarkable of them made its appearance suddenly near and north-west of the radiant-point above Capella at $6^h 35^m$ P.M., in full view of the observer, Signor Vergnano, without being preceded by any shooting-star. It formed a round white or yellowish nebular patch of light, about 2° in diameter, in the apparent position 71°, +45°. It slowly drifted a short distance towards the west, becoming elongated and assuming various shapes as it gradually grew fainter and yellower in colour. At $6^h 50^m$ its position was near α and λ Persii at 57°, +53°, and it disappeared at this place at $6^h 56^m$ P.M., having been constantly visible for not less than 21 minutes." Similar meteoric light clouds are stated by Padre Denza to have been seen in the November star-showers of 1868 and 1869 at Madrid and in the United States, and in the August meteor-showers of 1867 and 1872 by the observers at Modena and Urbino; a substance of unusual tenuity in such cases perhaps entering the atmosphere, and either emitting some denser shooting-stars at its collision, or remaining luminous alone at the point where it first encounters the upper strata of the air. "A more singular appearance, not exemplified in any former star-shower, took place at about $7^h 30^m$ P.M., during the greatest intensity of the shower. A cloud of faint greyish light, like a thin veil, spread itself in one instant over the wide space in Camelopardus between the Pole-star and the Lynx, with its centre at about 55°, +66°, and with a breadth of about 20°, hiding the faint stars in that direction. From this cloud Signor Vergnano and I beheld with surprise a perfect shower of meteors of the smallest size falling vertically on all sides, like the slenderest serpent fireworks, differing entirely from the star-shower that occupied the

* A process of equal-weight reduction, recommended by Mr. Glaisher, for levelling very abruptly varying observations, was three times applied to the meteoric rate-curve at Moncalieri before all the extraordinary oscillations which it presents were so considerably removed as to produce even the very irregular curve of frequency represented on the accompanying figure.

other portions of the sky, and continuing to appear as long as the principal shower was at its height until 5 minutes after 8 o'clock. The cloud then gradually dispersed, and at 8 minutes after 8 o'clock it left the portion of the sky which it had occupied as clear as it had been at first. So small and frequent were the meteors of this group that they could not be counted, and they were omitted from the enumeration of those which passed across that region of the sky."

Although many meteors of great brilliancy were seen, Padre Denza estimates the proportion of first-magnitude shooting-stars not to have exceeded the fifth or sixth part of the whole number visible. Their courses were short, their speed moderate, and their colour white or bluish white. A faint aurora was visible during a great part of the continuance of the shower.

These singular features of the display were not, however, recorded by the majority of the observers; but a faint aurora was observed at Palermo and at other places in Italy, which, owing to commotions of the sun's photosphere on that day, and not in the anticipation of any meteoric shower, Prof. Tacchini telegraphed to some distant stations would probably be visible during the night of the 27th. It was seen at Liverpool, and elsewhere in England; as well as a much brighter aurora at Bristol on the morning of the 24th.

The shower was seen at Bombay, beginning at 8 o'clock P.M., and lasting with great brilliancy for eight hours; at the Mauritius passing its maximum between 11^h and half-past 11 o'clock P.M. (where pulsations of the Aurora Australis were also seen); and at Parà in Brazil beginning at dusk and continuing until nearly midnight, besides at numerous places in Europe and the United States of America where it was carefully observed. From the nearly vertical descent of the meteors in Europe and America from a radiant-point overhead, their apparent paths and durations were short, and a few only of the brightest left very persistent streaks. It was remarked by Prof. Newton that the bodies themselves were without doubt smaller, and would therefore in any case be more quickly consumed than the usual August and November meteors. None were observed at Washington or Newhaven that would have appeared notable in either the display of August 10th or of November 14th. Among the 10,000 meteors counted at Glasgow Observatory by Professor Grant, only eight are described as having been as bright as Sirius or Jupiter; and about the same number were regarded by Mr. Lowe as sufficiently conspicuous for description among about 14,000 meteors, which he estimates to have been visible from his point of view. By Padre Denza about twenty meteors are stated to have been as bright as Jupiter or Venus among the 33,000 shooting-stars counted by his assistants. In a foggy and lamp-lit atmosphere on the Capitol at Rome, Padre Secchi reckoned only a fifth part as equal to second-magnitude stars, and a twentieth part as bright as first-magnitude stars. Of the latter kind 188 were recorded, and only thirty-three leaving phosphorescent streaks, among a total number of nearly 14,000 meteors seen there by his observers. One of these bright meteors was a fine bolide, leaving a bright streak visible for about 3 minutes. Prof. Tacchini states the numbers of various brightnesses seen at Palermo thus:—

	1st	2nd	3rd	4th	5th and 6th magnitudes.	
Numbers of meteors seen	10	1	40	53	698	(Total 802)

Of the ten first-magnitude meteors four were unconformable, and radiated from a point below Orion, leaving very persistent streaks. Among about 8000 meteors seen at Athens, Dr. Schmidt could also not include a single bolide having a sensible apparent disk. The average magnitude of the

meteors at all the stations where they were carefully described is regarded as not having much exceeded the fourth magnitude of the fixed stars. Orange, red, and yellow, and more rarely green, were the predominating colours of the brightest; and when thus conspicuous an aureole of red and yellow sparks surrounded the nucleus in mid course, while a short white streak was left for a few seconds, and very rarely for a few minutes, upon the track. The astronomer at Bordeaux, M. Lespiault, however, records ('Comptes Rendus,' 1872, Dec. 2nd) that "many of the meteors left bright streaks, some of which remained visible 10^{m} or 15^{m}, changing their shape and position in the sky slightly before they disappeared." The great majority of the meteors were mere points of dull white or yellowish light, without sparks or streak, moving with very moderate speed in short courses of from 4° to 6° only, attaining greater lengths of 10° or 15° and brighter white or bluish colour only in exceptional cases of the larger meteors of the shower; their extinction was always without explosion and quite gradual, but a few showed two maxima of brightness or intermittent light. A frequent peculiarity of the meteors was a curved or wavy course. This was noticed by Dr. Schmidt at Athens, by Prof. Newton at Newhaven, and by Mr. E. L. Layard at Parà in Brazil, who writes, "Some I saw apparently disappear for a moment and come out again, and two to my great surprise had a wavy course."

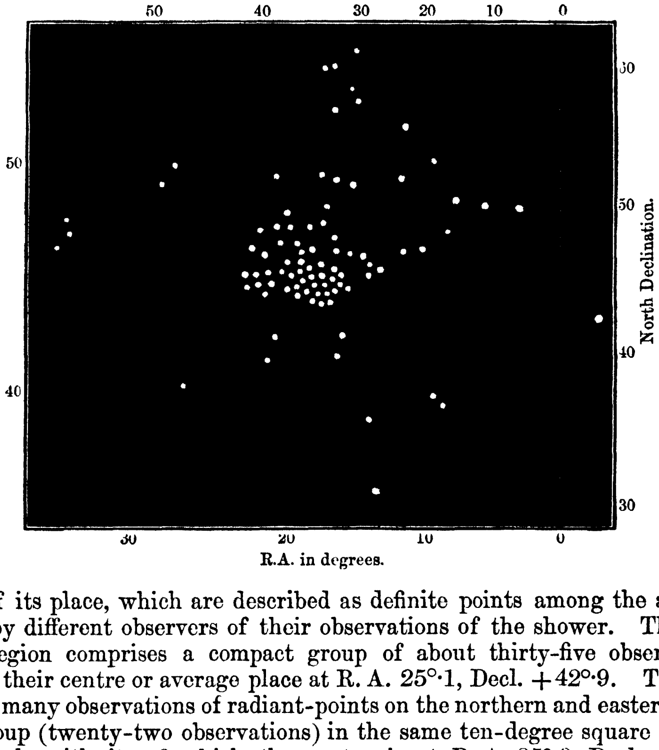
At the Mauritius, on the other hand, where the radiant was nearer the horizon in the north, the meteors had long courses, and frequently left long streaks upon their tracks. "The first meteor at $11^{h}\,22^{m}$ P.M. started from the tail-stars of Aries, and vanished south of the ecliptic. The train of this meteor was distinctly visible for 4 minutes, slowly wheeling from horizontal to vertical, and remaining 2 minutes vertical to the horizon. The other meteor, starting from a point at right angles to Aries and the Pleiades, passed through the Pleiades, Taurus, and Orion, and vanished near Sirius. Its luminous train was visible for more than a minute. Nearly all the meteors observed radiated from a point near Aries, at right angles with the Pleiades, and shot either like the last or transverse to it. A streak as broad as the head in all cases, and in 80 or 90 per cent. of them 10° or 20° long, remained visible on their tracks generally for a second or two. In the last two cases the broad bright streak was at least 40° long." (Messrs. Bruce and Hon. E. Newton.)

"From $10^{h}\,15^{m}$ to $10^{h}\,30^{m}$, the Hyades, Pleiades, and Orion being about 40° or 50° above the north horizon, the meteors appeared flying from north to south, and from N.E. to S.E. or from N.W. to S.W. on each side of north. Their rate of appearance was about one per second, two or three sometimes appearing together. The nearer ones every few minutes showed trains and sparks like a rocket, varying from 2° or 3° to 5° or 6° in length, and seldom reaching 10°. Towards 11 o'clock fewer seemed to be falling than before." (Messrs. A. C. M'Pherson and Hon. Robert Stein.)

In lat. 19° 52′ S., long. 50° 25′ E., Captain Gaston of S. 'Penelope,' "saw an extraordinary star-shower beginning at about $7^{h}\,30^{m}$. The meteors shot from north towards south-east. Some of them were bright, others leaving only a slender streak, and this display lasted until 2^{h} A.M." The radiant in the Mauritius must have been near $o\,\zeta$ Persei, and the time of maximum of the shower at or soon after 11^{h} P.M. (Mr. C. Meldrum's report on the shower in 'Nature' of January 23rd, 1873.)

The radiation of this star-shower was very scattered, and the positions assigned to it by various observers often differed very considerably from each other. Thus the last-mentioned position assigned to it by Mr. Meldrum from the observations at the Mauritius, is at about R. A. 54°, Decl. + 31°;

while an observer near Dublin, Mr. M. H. Close, describes its position as near ξ Andromedæ at R. A. 19°, Decl. + 45°; and independently of their geographical position, such differences are found among the notes of many observers of the shower. The great majority of the best determinations of its place are, on the other hand, very near the latter place. The accompanying diagram shows the recorded positions, from ninety independent determina-



R.A. in degrees.

tions of its place, which are described as definite points among the accounts given by different observers of their observations of the shower. The principal region comprises a compact group of about thirty-five observations, having their centre or average place at R. A. 25°·1, Decl. +42°·9. There are besides many observations of radiant-points on the northern and eastern side of this group (twenty-two observations) in the same ten-degree square of R. A. and Decl. with it, of which the centre is at R. A. 25°·9, Decl. + 46°·7, forming an apparent diffuseness of the principal radiant region in that direction. Lastly, the average position of all the outlying radiant-points (thirty-three observations) is at R. A. 23°·0, Decl. +45°·3, and the average position of all the ninety observations projected in this map, at R. A. 24°·54, Decl. +44°·74, can scarcely be more than half a degree from the general direction of these numerously recorded centres of divergence of the shower. The position fixed by Mr. Hind's computation of the radiant-point of particles of Biela's comet had the shower been visible at the comet's last return in 1866 is at R.A. 25°·25, Decl. +42°, not quite 3° southward from the general radiant place, and 1° south of the mean principal or central radiant-point of the shower as found by these observations of its recent great appearance in November 1872.

The November Meteoric Shower in 1872.—The annual appearance of the star-shower on the morning of the 14th of November, 1872, was observed at the Lyceum at Matera, in Piedmont, by Signor Viso Eugenio; and from the numbers seen, it appears to have been of considerable brightness. The following were the hourly numbers counted. Although the number of the

observers is not stated it was probably four, the number who watched the appearance of the following star-shower on the 27th of the same month, and who counted during the whole of that single night 44,644 shooting stars! (Communicated by G. V. Schiaparelli and Padre F. Denza).

Total numbers of shooting stars seen at Matera, Italy, on the morning of November 14th, 1872, in the half-hours ending at—

	$12^h 30^m$ A.M.	1^h	$1^h 30^m$	2^h	$2^h 30^m$	3^h	$3^h 30^m$	4^h	$4^h 30^m$	5^h	$5^h 30^m$	6^h	Total.
Nos. of meteors seen	7	10	9	13	17	25	41	79	122	149	109	57	638

Star-showers of December 12*th*, 1872, *and January* 2*nd*, 1873.—From the effect of bright moonlight and of a cloudy sky, no observations of the December meteors in 1872 could be obtained. The sky was equally overcast on the night of January 1st, 1873; but accounts in the newspapers ('Daily Telegraph') of the 3rd mentioned the occurrence of several bright meteors on the morning of the 2nd of January between 1^h and 2^h A.M. at Wrexham. On the night of December 31st, Mr. Denning traced the paths of twelve meteors in 3 hours on a map, without perceiving a distinct radiant-point, the principal centres of divergence being apparently near δ Leonis, α Geminorum, and in Ursa Major. The sky was clear, and the light of an aurora rather bright in the north.

On the night of January 2nd the sky was clear between storm-clouds at Bristol, and Mr. Denning saw an intense flash of lightning (which was perhaps meteoric) from the south, at Bristol. But shooting-stars at this place and at other stations where the sky was clear were exceedingly scarce until midnight, not more than two or three small ones appearing in an hour. The largest number counted was six meteors per hour, by Mr. Wood at Birmingham, of which only one diverged from the usual radiant-point of the January shower. The appearance of the star-shower at Wrexham on the morning of January 2nd was, however, fully confirmed by Mr. Backhouse at Sunderland, who in a watch kept between 5^h and 7^h A.M. on that morning, recorded the paths of 31 meteors, the rate of their appearance being 37 per hour for one observer. The radiant-point, or rather the centre of a radiant area, which seemed to be 7° or 8° in diameter, was at R. A. 234°, N. Decl. 48°, within 3° of the position near ϵ Quadrantis, where it was observed by Professor Herschel on the 2nd of January, 1864 ('Report' for 1864, p. 98), and agreeing well with the bright character of the display, and with the great scarcity of meteors on each of the adjacent nights, in marking the shower as a very well-defined reappearance of the January meteors of that periodic date.

On the nights of the 25th and 27th of February, 1873, bright meteors were seen by Mr. H. W. Jackson at Tooting, who drew attention to their appearance as perhaps indicating special star-shower dates. On the latter night several bright meteors were also noted by Mr. Denning at Bristol while observing Jupiter through a telescope, without paying particular attention to record their numbers and directions. A bright flash like lightning appeared behind a cloud in the south at $10^h 30^m$, the rest of the sky being clear; and a bright shooting-star observed at $7^h 30^m$ was recorded simultaneously by Mr. Denning and by Mr. Jackson at Tooting (see the foregoing list of double observations).

The April Star-shower in 1873.—On the nights of the 19th and 20th of April, 1873, the sky was in general clear, with fog or clouds at some stations

only, but on the 21st it was generally overcast. In London, and at Bristol, Street (near Bath), York, Sunderland, and Newcastle-upon-Tyne, observations of some hours' duration on each night were made; and a list of shooting-stars was also recorded on the night of the 21st by Mr. Denning at Bristol. The number of meteors from Lyra did not exceed that of the unconformable meteors (amounting together to about eight per hour) on either of these periodic nights; but the proportion observable on the 19th was slightly higher than on the other nights. A long-continued watch was kept by Mr. Lucas at the Radcliffe Observatory at Oxford from 10 o'clock P.M. until half-past two, and half-past one o'clock A.M. on the nights of the 19th and 20th of April respectively, with similar results. The centre of the April meteor-stream appears from these observations to have been crossed by the earth during the daytime of April 20th, when daylight intervening between two slender indications of the shower must have caused the period of its greatest intensity to pass unobserved. Four double observations of shooting-stars occurred among the lists recorded on the first two nights, descriptions of which are contained in the foregoing catalogue of such identifiable accordances.

The August Meteors in 1873.—The observations of this annual shower were much incommoded by clouds, and the brightness of the full moonlight concealed a large proportion of the meteors of the shower, which would otherwise have been visible. On the night of the 10th the sky was everywhere completely overcast, and on that of the 11th so much so that a continuous record of the numbers seen could not be obtained at any of the observers' stations. The following are the numbers seen at Bristol by two observers, looking towards the N.E. and N.W. quarters of the sky, during successive quarters of an hour, ending on the night of the 9th of August at

	$10^h 30^m$,	45^m,	11^h,	15^m,	30^m,	45^m,	Totals in $1^h 15^m$.
Nos. of meteors seen in the N.W. (C. P. Denning).	2	3	0	1	2	1	9
Nos. in the N.E. (E. Barker)....	9	4	1	5	3	4	26
Total numbers seen	11	7	1	6	5	5	35

On the night of the 11th Mr. Denning found them to be more frequent than on the 9th, and the appearance of their display was that of an August star-shower of somewhat considerable brightness. At the other stations it was not found possible to count the meteors, as at Bristol, so as to trace the progress and apparent brightness of the shower on account of the frequent interruptions from the general prevalence of cloudy skies; but a continuous watch kept at the Radcliffe Observatory, Oxford, by Mr. Lucas, for about four hours on the night of the 9th, and for an hour and a half on that of the 11th, corroborates Mr. Denning's observations. About 50 meteors were mapped at all the stations in a total watch of about 7 hours on the 9th, and about 30 meteor-paths in a total watch of about 3½ hours on the 11th. Those meteors of the collected list which were simultaneously observed at two or more stations in the watch are described in the above catalogue of double observations. The position of the radiant-point and other particulars of the appearance of the shower will be examined for comparison with the observations of the previous year, when the necessary projections of the meteor-tracks can be completed.

Meteors of September 1st, 1873.—Quite an abundance of bright meteors (as communicated by Mr. J. E. Clark) was seen at Street, Somersetshire, on the night of the 1st of September, 1873. Nine meteors, some of them very fine ones, were seen between 11^h and 12^h P.M., mostly in the south; but the directions of their apparent paths were not noted with sufficient accuracy to determine the place of their radiant-point, or if all the meteors of the display diverged very definitely from a common centre.

IV. Papers relating to Meteoric Astronomy.

The discussions relating to the second great star-shower in November, now known to be connected with Biela's comet, occupy the principal place of interest among the various published papers on meteoric astronomy during the past year. In the Reports of this Committee for the years 1868 (p. 399) and 1869 (p. 305), the communications of Professors d'Arrest and Galle on the connexion of certain comets with meteor-showers are briefly abstracted from two Numbers (1633 and 1635) of the 'Astronomische Nachrichten' of the month of March, 1867 (the same apparent connexions having already been announced by Dr. Weiss, of Vienna, in the next preceding No. 1632 of the same Journal), with some errors and omissions which require correction. The star-shower indicated by d'Arrest differs entirely from the principal December star-shower of December 11th–13th, there supposed to be signified, whose radiant-point is between the constellations Gemini and Auriga. That indicated by Prof. d'Arrest is a star-shower, having a more north-westerly radiant-point in Andromeda, appearing in the British Association list of 1868 as A_{16} (Nov. 23–Dec. 18), connected perhaps with $A_{14,\ 15}$ of an earlier date, and in Dr. Heis's list of the year 1867 * as A_{18} and A_{19} in the latter half of November and beginning of December, whose positions are all in or near the constellation Cassiopeia. It is pointed out by Prof. d'Arrest that meteoric showers having this direction occurred on the following dates:—

A.D. 1741.	A.D. 1798.	A.D. 1830.	A.D. 1838.
Dec. 5.	Dec. 6.	Dec. 12. [?A bolide only.]	Dec. 6 & 7.

which may be supposed to be connected with the passages of the earth through the node of the orbit of Biela's comet. On the last of these dates the position of the radiant-point was found by Flaugergues in France, and Herrick in the United States to be near Cassiopeia, at about 30°, +40° for the former, and in less R. A. and greater declination for the latter observer's estimate of its position.

In 'Nature' of Jan. 16th, 1873, Mr. T. W. Webb thus recalls some excellent observing-notes of that star-shower, which he formerly reported with many similar notes to the late Professor Baden Powell:—"1838, Dec. 7. A great number of falling stars were observed between 6^h and 7^h P.M. In about half an hour 40 were counted, sometimes by one, sometimes by two, sometimes by three observers, two at a medium. They were of all magnitudes up to the first. The larger dissolved into a train of light, but left no train behind them. The S. and W. quarters were chiefly observed, but their prevalence seemed to be universal. They all fell in nearly a vertical direction; but those in the N.W. and S.E. quarters inclined towards S.W. [*i. e.* the radiant-point was not far from the place occupied by it in November 1872]. The colours of the more conspicuous ones seemed to verge towards orange. Their courses were of no great length. There was at the same time a pale

* Astronomische Nachrichten, No. 1642. See end of this Report.

† These Reports, 1852, p. 185.

auroral light along the north horizon, extending from N.W. to N.E., apparently equally extended on each side of the true meridian. The meteors were not watched after 7^h; but about 11^h, on looking out again, I saw one, the only one in several minutes in the S.W.; but it had now no longer a vertical direction, its course pointing now to the N.W." The endeavours of the Committee to consult an account of the same phenomenon by Mr. Maverly at Gosport, if it was published as stated by Mr. Webb, have not hitherto been attended with the success that will, perhaps, await the further continuation of their search.

An error of omission is also contained in the above-mentioned abstracts of the Papers of d'Arrest and Galle; as it is not observed that the latter as well as the former astronomer pointed out the probable connexion of such meteoric showers with Biela's comet. At the close of his note on the cometary character of the April star-shower, Dr. Galle adds:—"Amongst other comets yielding meteor-showers, if some overtake the earth they would appear more deflected from their real orbits than meteor-streams arriving from the opposite direction. As an example of this kind, I calculated the radiant-point of the comet of Biela at its descending node, since the date of this (Nov. 28th) is found to occur in a period of considerable frequency of meteors; but I have not found in all the observations to which I could refer that the date of Nov. 28th is especially distinguished from other days near it; and it appears to be connected with the weeks immediately preceding and following it in the prevalence of meteoric displays. The comet's direct motion makes the date of its nodal passage less fixed and less certain, and the agreement with observations accordingly less likely to be so perfect in the case of this comet as in other cases. Yet renewed observations on the night of the 27th of November certainly deserve to be very carefully repeated." (Breslau, March 11th, 1867; 'Astronomische Nachrichten,' No. 1635.) D'Arrest's communication in the 'Astr. Nachr.' No. 1633, is dated Copenhagen, Feb. 25th, 1867. The calculations showing the probable connexion of two comets (1861, I., and Biela's comet) with the April and November to December star-showers by Dr. Weiss, are contained in an earlier No. (1632) of the 'Astronomische Nachrichten.' The latter memoir was extended and completed by Dr. Weiss in the 'Astronomische Nachrichten,' No. 1710, and in the valuable paper presented to the Academy of Sciences at Vienna on the 16th of January, 1868, 'Beiträge zur Kentniss der Sternschnuppen' (see these Reports for 1869, p. 304).

A short review of the above predictions was presented to the Royal Astronomical Society ('Monthly Notices,' vol. xxxii. p. 355) during the summer of last year in preparation for the expected approach of Biela's comet to the neighbourhood of the earth's orbit in the latter months of the year; and the attention of astronomers appears to have been already drawn to the favourable prospect of a meteoric shower from the above-cited papers sufficiently to make its character at once decided by the majority of the observers when the abundant star-shower was observed. Prof. Klinkerfues at Göttingen, whose observations of the shower were most complete, immediately dispatched an instruction by telegraph to Mr. N. Pogson, the astronomer at Madras, to search the portions of the sky opposite to the radiant-point for any cometary body which might be visible in the direction of the departing and retreating meteor-group through which the earth had passed. Such a comet was found by Mr. Pogson on the 2nd of December, about 13° from the place of the anti-radiant-point, and close to the position pointed out by Dr. Klinkerfues. Another observation of it was obtained on Dec. 3rd, and there is sufficient resemblance in the observed track of the comet to that which meteors con-

nected with Biela's comet might pursue to make it probable that this telescopic body is at least a member of the cometary group, of which it is not impossible that the double comet of Biela may contain other representatives hitherto not detected by telescopic observations*. Should the principal bodies of Biela's comet have undergone no uncalculable perturbations, it is shown by Mr. Hind ('Monthly Notices,' vol. xxxiii. p. 320) that up to its expected return in the year 1866, no calculable causes depending upon its actual position until that time have been overlooked, and that if uninvestigated disturbances may yet explain its presence in the recent meteor-shower at a place of its orbit which it should have passed at least twelve weeks before the date of the meteor-shower, those disturbances must have affected its course during the last revolution (1866–73) which the comet has performed. It appears more probable that the comet has faded out of sight; and it is pointed out by Professor Schiaparelli, in a new volume of three lectures on meteors published in connexion with these recent discoveries at Florence, that more than one instance of variability has been observed in comets, of which the two portions of Biela's comet itself presented a remarkable example at the last return, when interchanges of brightness were observed between them. It may also be added that when first discovered to be periodical in the year 1826, it was found to be identical with a comet observed in the years 1772 and 1805, having accordingly escaped observation during two previous series of returns in this and the last century, when it might be expected to have been detected, had not some diminution of its light, perhaps, rendered it invisible on each of those occasions. Telescopic and meteoric observations may thus be found, if perseveringly conducted and comprehensively carried on together, to assist each other in tracing the effects of the sudden variations in their physical condition to which comets, from their small masses and highly eccentric orbits, are exposed, more than all other classes of astronomical bodies, in their circumsolar revolutions.

The newly discovered connexion between meteor-showers and comets, according to which the periodic comet of Biela and the recently observed star-shower are associated members of a common stream of bodies following each other in nearly the same path about the sun; and the question of the probable nature of the physical connexion between the invisible particles of the meteor-stream, and the faintly or brightly luminous body of its attendant comet, have given rise to considerable discussion respecting the extent and mode of the connexion in which comets in general, and all the different forms of meteoric substances may possibly be regarded as allied phenomena. With respect to appearances of the latter class, it must be admitted that many of the grounds for such conclusions regarding detonating fireballs and aërolites are hitherto very indefinite and uncertain. The directions and real velocities in space of very few aërolites and detonating meteors have been exactly ascertained; while, on the other hand, the collected proofs derived from observations of a distinct connexion between star-showers and periodic comets are as abundant and precise as the most rigorous process of research in any kindred subject of scientific inquiry would demand. Reviewing certain instances of hyperbolic velocities of fireballs and aërolites that have been sufficiently well observed to be accepted as examples of their class, and contrasting the evidence which they present with the remarkable absence among comets of very excentric hyperbolic orbits, Prof. Schiaparelli is led to recognize two different original sources of these two classes of bodies, and to regard comets as cosmical bodies belonging to the same star family, or "star-

* Astronomical Society's 'Monthly Notices,' vol. xxxiii. pp 128 & 130.

drift" as the sun, and some aërolites and fireballs as derived from more distant regions of the fixed stars, the direction and speed of whose motions in space (as gathered from the recent researches of Dr. Huggins and Mr. Proctor) resemble each other, but differ considerably from those of the sun. As examples of hyperbolic velocities among fireballs and aërolites are of rather rare occurrence, it is, however, admissible to regard these instances as exceptional cases, and not as the normal representatives of their class*. In that case aërolites, as well as shower-meteors, may be parts of cometary systems; and it is not impossible that the extraordinary meteorological changes which comets undergo from the excentricities of their orbits, may, by the process of a kind of 'weathering,' disintegrate their surfaces sufficiently to scatter such bodies in crowds along their paths†. In this view, instead of presupposing the existence of cosmical clouds containing all these several bodies separately formed, comets may be regarded as parent bodies, from which aërolites and shower-meteors are similarly derived. Adopting a special theory of the origin and of the physical constitution of comets, Zöllner explains the production of such star-showers as that which was witnessed last November, by a process very similar to the last‡. Supposing the remnants of a shattered star or planet to be scattered by some catastrophe into intrastellar space, besides the materials of aërolites and detonating fireballs which would result, it may be assumed that fluid masses, as of their seas (and possibly hydrocarbons) and other easily volatilizable substances would occur among the *débris* of such a shock. Among the fluids and easily vaporizable materials thus ushered into space, and there maintained as liquids or solids by cold, and by their own attractions, the sun's heat acting upon their otherwise fixed masses, when first drawn into its immediate neighbourhood, would effect a surface distillation sufficiently abundant to detach some vaporous portions from their spheres, or even to volatilize them completely, and to efface them after many periodic revolutions from the sky. These vapours might possibly recondense afterwards into solid dust or drops, to assume the form of meteor-streams along the cometary orbit, producing on their collision with the earth's atmosphere, the extraordinary phenomena of star-showers§. In accepting such explanations of their origin, it must be borne in mind that the streams of meteor-particles with which some periodic comets are associated are altogether differently constituted from the tails and envelopes of such comets, in obeying, as far as has yet been discovered, without any deviations like the extraordinary exceptions which those appendages present, the simple law of universal gravitation which governs the

* Schiaparelli, 'Entwurf einer Astronomischen Theorie der Sternschnuppen' (Stettin, 1871), pp. 207–210, and 216–229.

† Ibid. pp. 212–13.

‡ F. Zöllner, "Ueber den zusammenhang von Sternschnuppen und Cometen," Poggendorff's Annals, vol. cxlviii. pp. 322–29. See also 'Ueber Die Natur der Cometen' (Leipzig, 1872), by the same author, p. 109.

§ That even mineral substances are gradually volatilized at comparatively low temperatures, and sublime or are recondensed in appreciable quantities, is shown by some remarkable experiments by the Rev. W. Vernon Harcourt on various minerals placed for many years under the hearth of an iron smelting-furnace, as described in the volume of these Reports for 1860, p. 175 *et. seq.* (with coloured plates). Under the action of a prolonged heat, in which neither copper, zinc, lead, nor tin were melted, the oxide of copper which formed a crust upon the plate of that metal, had sublimed, and deposited itself in red crystals along with sublimed metallic copper, not only upon the surface, but also in the interior of the neighbouring piece of lead. The adjacent pieces of the other metals were similarly calcined, and coated with a thick crystalline crust of their oxides which had diffused itself in a similar manner among the substances of the surrounding blocks (see the explanation of the experiments and of the plates, at pp. 188 and 192 of that Report).

motions of the planets and of the comets in their paths. It is also important to observe that among the spectra of several telescopic comets which have been examined, there is a typical resemblance which leads us to infer that the coma or envelope of such comets is at least in great measure composed of gases shining, for some reason, with self-resplendent light. A state of liquid or solid aggregation of vaporizable materials by extreme cold cannot on this account be regarded as a complete explanation of the original condition of their nuclei, unless, with Zöllner, we admit that a feeble electrical excitation accompanies the development of the vapours from them that produce the envelope and tail; and that a restoration of the disturbed electrical equilibrium among these vapours produces in them (as in the extensive tracts of auroral clouds) a sufficiently strong illumination to be visible on account of their great depth; as even bright auroral beams may be produced by weak electrical discharges lighting up vast volumes of air through which they pass. The free electricity with which the vapours are charged would be sufficient, as shown by Dr. Zöllner, to account for the rapid projection of the extremely rarefied materials of the tail in an outward direction from the sun, if its tension, and that of free electricity similarly present in the sun itself, is supposed not to exceed the amount assigned by Hankel as the ordinary tension of free electricity in the earth's atmosphere. On account of their larger masses (compared to the surfaces, upon which electricity resides) no sensible effect of repulsion is produced by solar electricity on the nucleus, and on the larger fragments separated from the comet's mass, that appreciably diminishes the force of universal gravitation upon them, to which, in common with all other bodies coming within the sphere of the sun's attraction, the separate particles of the cometary cloud are principally subject. Similar views to those of Dr. Zöllner on the electrical origin of the sun's repulsive force on the tails and envelopes of comets (a force whose intensity was first mathematically investigated by Bessel) were previously entertained by Olbers, and discussions of some of their principal consequences, with excellent illustrations derived from cometary observations by M. Faye, will be found in the 'Comptes Rendus' (vol. xlviii. p. 421) for 1870, and in a contemporary number of the French 'Revue des Courses Scientifiques.' The theory of a self-luminosity in comets, and perhaps in the vaporous nebulæ, resembling the glow-discharge in the vacuum of a barometer-tube when the mercury is shaken, suggests, as shown by Dr. Zöllner, no insuperable difficulties, when the enormous thickness of the vapour-tracts is considered, in which a very feeble illumination of this description would be sufficient to render them very discernibly self-luminous, with all the visible characters of a glowing gas.

During the last two or three years the discovery of energetic forces of eruption on the sun, and therefore also probably on the surfaces of the stars, has demonstrated the occasional occurrence of some convulsions so extremely violent that they would suffice (at least, if they were but little stronger, or equally energetic at an earlier period of the sun's history, when its diameter was somewhat larger) to project molten and gaseous matters from its mass to distances beyond the sphere of its own attraction. One of the most violent eruptions of this description was observed by Prof. Young in America on the 7th of September, 1871, when masses of glowing hydrogen left the sun's surface with a velocity of projection which cannot have been less than 200 miles per second; had it started with this velocity from an elevation but little more than twice its actual distance from the sun's centre, it would have been projected beyond the orbit of the planet Neptune, and a velocity of

projection from the sun's present surface of 380 miles per second would have sufficed to carry it beyond the limits of the solar system never to return*. The existence of such forces, and the evidence which the microscope affords that aërolites have had their origin among mineral masses in a state of fusion, if not of vapour, combine to support a theory formerly entertained by other writers, and recently announced most definitely by Mr. Proctor in England † and Prof. Kirkwood in America as an "astro-meteorological hypothesis" of the origin of meteors and meteorites. By a still more remarkable supposition Mr. Proctor proposes to regard the class of periodic comets with their attendant trains of meteors as originally projected from the major planets Jupiter, Uranus, or Neptune, in the neighbourhood of whose orbits it is well known that the greater number of their aphelia are placed; and some peculiarities of the light as well as of the dense atmosphere of the largest of these planets, Jupiter, renders it probable that it is partially self-luminous, and that it still continues to be in a more sunlike state than the smaller primary and secondary planets of the solar system‡. A close appulse of the November meteor-comet to the earth is pointed out by Mr. Hind as having probably occurred in the year 1366, when it was observed in China in the same month of October with the memorable star-shower recorded in some parts of Europe in that year. Another visible return of the comet appears to have taken place in 868, when its path among the constellations was also recorded in China, and appears to be in good agreement with the orbit of the present comet§. It also appears that the November meteor-shower may be of older date than the period assigned by M. Le Verrier (A.D. 126) to its last encounter with the planet Uranus, a previous encounter with that planet not less close having been shown by Prof. Kirkwood (in the journal above quoted, p. 338) to have taken place in the year B.C. 43, while the next close appulse of the comet to the planet will happen in the year 1983.

A general list of approximate agreements between orbits of comets and those of observed meteor-showers, extracted from the works of Weiss, Schiaparelli, and Schmidt, will be found collected, exclusive of the four well-known examples of perfect correspondence in the cases of the April, August, and two great November showers, in the Report of the Council to the last Annual General Meeting of the Royal Astronomical Society, where the length of the list, and a due regard for the limited space of this Report, will only permit its insertion to be noticed ||; but a peculiarity in two of the accordances appears to claim exception in order to explain the supposed agreements which they present. In the early parts of April and August two meteor-showers are found to proceed, the former from a radiant-point between Corona and Boötes, and the latter from near the north pole of the heavens, agreeing well with the radiant-points of corresponding comets whose line of nodes the earth encounters at those dates. But the orbits of these comets falling far within the orbit of the earth, it is not possible that an encounter of the earth with any meteors lying upon their tracks could be produced. These accordances must therefore be rejected, unless, with Weiss and Schiaparelli, it is

* "Astro-meteorology," by Prof. D. Kirkwood, U.S., 'The Popular Science Monthly,' 1871, p. 335.

† 'Cornhill Magazine,' November 1871.—In the 'Proceedings of the Royal Society,' vol. xiv. pp. 120–129, March 1865 (see these Reports for 1865, pp. 132 and 140), the late Prof. Brayley, founding his observations on the microscopical investigations of Mr. Sorby (vol. xiii. of the same 'Proceedings,' p. 333), strongly maintained, although he somewhat less lucidly developed, the same hypothesis.

‡ "The Origin of the November Meteors," by R. A. Proctor, Monthly Notices of the Royal Astronomical Society, vol. xxxiii. p. 45. § Ibid. p. 49. || Ibid. p. 260.

supposed possible that some parts of the cometary substance, repelled from their proper orbits by the sun in the form of the tail and other luminous appendages emitted by the comets near their perihelion passages, may have extended to such a distance in their orbit-planes as to intersect the orbit of the earth. It is known that substance repelled in this manner from the comet, if it consists of materials capable of finally gravitating towards the sun, will describe closed orbits round it, and might thus periodically produce the appearance of a corresponding meteor-shower. For the purpose of an approximate comparison with the known meteor-showers, the repelled particles may be assumed to move in orbits which differ little from those of their derivative comets, excepting in having a larger perihelion distance.

In order to complete and facilitate, as far as possible, the comparison of meteor-streams with the orbits of known comets, lists of observed radiant-points of meteor-showers continue to be compiled and recorded by observers, an important contribution for that purpose during the past year being the "Catalogue of Observed Radiant-points" obtained by Captain G. L. Tupman from his observations of shooting-stars made in the Mediterranean during the years 1869–71*. This list contains the places of 102 distinct radiant-points, independently determined, and for the most part confirming the results presented in the earlier catalogues of other observers. Thus, in about sixty cases, the same showers appear to have been recorded by Dr. Schmidt † at Athens; and the agreements with the general list of radiant-points for the northern hemisphere, exclusive of Dr. Schmidt's results (see the last Report), compiled by Mr. Greg are equally numerous. Captain Tupman regards fifty-eight of the meteor-showers described in his list as identical, and twenty-one others as fairly in accordance with those of other observers; of the remaining twenty-three positions, nearly the whole may be regarded as well determined and as probably true radiant-points. Among the brightest showers and the most conspicuous radiant-points were remarkable displays of about fifteen or twenty shooting-stars per hour on the nights of April 30th and May 2nd, 1870, from the direction of a point at R. A. 325°, S. Decl. 3°; and showers of less abundance on March 7th, September 8–10 and 13–15, and October 5–10, 1869, and November 1–9, 1869 and 1872: the last was the well-known shower from Taurus in the early part of November; and a good average position of its apparently double radiant-point in about R. A. 53°, N. Decl. 12°, and R. A. 57°, N. Decl. 20°, was obtained by several well-agreeing observations on successive nights.

The following corrected Table of radiant-points, compiled and published by Dr. Heis in April 1867 ('Astronomische Nachrichten,' No. 1642), was included by Mr. Greg in his general list of radiant-points contained in the last volume of these Reports. In a future continuation of that list it will be attempted to condense and to add to it a similar reproduction of the new materials afforded by the two ample catalogues of Dr. Schmidt and Captain Tupman, of which no comparison has yet been included in its collection. A suitable analysis of their contents will thus complete the discussion of all the known radiant-points of shooting-stars of which published or private information has hitherto been obtained by the Committee. It is proposed to exhibit the results of this examination on maps of a special kind, adapted to assist observers in recognizing immediately the particular radiant-points or showers to which any observed meteor-tracks might correspond, and thus to enable

* Monthly Notices of the Royal Astronomical Society for March, 1873, vol. xxxiii. p. 298.

† In his Catalogue of Radiant-points for successive months of the year, 'Astronomische Nachrichten,' No. 1756.

them to arrange and classify their observations. It is further intended to accompany the maps with a printed catalogue of Captain Tupman's observations, only a certain proportion of which are designated in the catalogue as belonging to some of the numerous meteor-showers included in his list, while the greater number have not yet been distinguished as conformable to any known centres of radiation from which they may very possibly have been derived. A complete analysis of the catalogue, and of the scattered observations collected for the Committee within the last few years by observers for the British Association, will during the present year occupy the attention of the Committee, and will continue to engage their consideration with the best opportunities and facilities for reducing and arranging them under their proper radiant-points which it will be in their power to bestow on their discussion.

List of Corrected Radiant-points by Dr. Heis, 'Astronomische Nachrichten,' No. 1642 (May 1867).

Half-monthly, Monthly, or Meteoric Periods and Positions of the Radiant-points.			
R.A. N. Decl.	R.A. N. Decl.	R.A. N. Decl.	R.A. N. Decl.
January 1–15. A_1 ... 28° +50° K_1 ... 227 +54 M_1 ... 145 +51 N_1 .. 290 +84	February 15–28. A_4 ... 76° +40° M_4 ... 173 +63 N_4 ... 245 +76 S_1 ... 174 +16	April 1–15. A_7 ... 84° +45° M_7 ... 180 +49 N_7 ... 260 +86 S_4 ... 185 +22	June 1–30. N_{10}... 158° +83° B_2 .. 333 +42 Q_2 ... 242 +12 W ... 292 +15
January 16–31. A_2 ... 30 +61 K_2 ... 227 +60 M_2 ... 169 +45 N_2 ... 35 +87	March 1–15. A_5 ... 50 +49 M_5 ... 120 +54 N_5 ... 15 +80 S_2 .. 181 + 6	Period of April 20. A_8 ... 58 +66 M_8 . 160 +49 N_8 ... 275 +83 S_5 ... 199 +14 C ... 277 +38	July 1–15. N_{11}... 20 +85 A_9 ... 41 +62 B_3 ... 315 +54 Q_3 ... 262 +12
February 1–14. A_3 ... 61 +56 M_3 ... 171 +56 N_3 ... North Pole.	March 16–31. M_6 ... 150 +47 S_3 ... 176 +16	May 1–31. N_9 ... 315 +79 S_6 ... 202 + 9 B_1 ... 325 +55 Q_1 ... 232 +27	July 15–31. A_{10} .. 51 +55 B_4 ... 320 +70 N_{12}... North Pole.
Period of August 10. A_{11}... 51 +55 B_5 ... 297 +68 N_{13}... 345 +85	September 16–30. A_{14}... 44 +63 B_8 ... 311 +65 N_{16}... 65 +84 T_3 ... 1 +11 R_2 ... 46 +37	Period of Nov. 14. P_2 ... 46 +43 A_{17}... 15 +62 D ... 279 +56 R_1 ... 55 +16 L ... 148 +24	December 16–31. A_{20}... 37 +59 N_{21}... 340 +89 K_3 ... 235 +52
August 16–31. A_{12}... 35 +61 B_6 ... 306 +59 N_{14}... 295 +79 T_1 ... 314 +15	October 1–15. A_{15}... 51 +61 N_{17}... 105 +81 R_3 ... 45 +32 B_9 ... 315 +65	November 19–30. A_{18}... 15 +62 N_{19}... North Pole. P_3 ... 45 +44	
September 1–15. A_{13}... 35 +63 B_7 ... 293 +57 N_{15}... 130 +84 T_2 ... 343 +10 R_1 ... 53 +35	Period of Oct. 16–31. P_1 ... 23 +40 A_{16}... 72 +44 B_{10}... 334 +54 N_{18}... 205 +85	Period of Dec. 1–15. A_{19}... 21 +54 N_{20}... 123 +78 M_9 ... 112 +39	

On the Visibility of the dark side of Venus. *By* Professor A. Schafarik, of Prague.

[A Communication ordered by the General Committee to be printed *in extenso*.]

It is well known that the unillumined side of the planet Venus has been sometimes seen shining with a faint grey light, like the dark side of the moon when illumined by the earth.

Schröter in 1806 thought he had made for the first time this remarkable observation; but it was found afterwards that Harding had made it almost simultaneously, and Olbers pointed out an old observation made by A. Mayer at Gryphiswald in 1759. Arago found a still older observation of the same kind made by Derham at a date not fixed, but certainly anterior to 1729, the date of publication of the French edition of his 'Astrotheology.'

Nevertheless this phenomenon is stated in the best text-books of astronomy to be one of the utmost rarity. Mädler knows only two observers of it, the profoundly learned Humboldt only three, Arago only five; and even recently Dr. Winnecke, of Karlsruhe, believed that he was the only witness of that phenomenon in daylight since the time of A. Mayer; but under these particular circumstances it has been seen by eleven observers, and by five of them more than once.

It was known to me for a long time that there were on record far more observations of this phenomenon than is ordinarily supposed; and when, some years ago, I happened to be a witness of it myself, I undertook to collect all existing observations of it.

This I have now done; and as I have succeeded in collecting the surprising number of twenty-two observations, many of them repeated more than once, a short account of what I have found will perhaps be not uninteresting to astronomers.

1. The first observation recorded is that of William Derham, Canon of Windsor, referred to in his 'Astrotheology' as made in the perigeum of Venus, probably in bright twilight, when he saw the dark side of the planet shining with a dim reddish light. Arago, who mentions this observation, quotes from a French translation published in 1729. It would be interesting to know if this observation is found also in the first English edition published in 1714.

2. The second in order was Christian Kirch, first astronomer of the Royal Academy of Sciences at Berlin. He saw the phenomenon twice (June 7, 1721, and March 8, 1726), both times with moderate optical power and in bright twilight. He remarked that the bright crescent was apparently a part of a larger sphere than the faintly shining dark side. (Astronomische Nachrichten, No. 1586, vol. lxvii. p. 27.)

3. Third came Andreas Mayer, Professor of Mathematics in the Gryphiswald University, who, on October 20, 1759, observed Venus, culminating only 10° from the sun, with an unachromatic transit-instrument of only $1\frac{1}{2}$-inch aperture, and saw the whole disk "like the crescent moon which reflects the light of the earth." (Observationes Veneris Gryphiswaldenses, 1762, p. 19. Schröter, Beobachtungen des grossen Cometen von 1807, Appendix, p. 74.)

4. The fourth witness is Sir William Herschel, who about 1790 several times saw a part of the limb of the dark side in a faint light. Neither date nor time of day is given. (On the planet Venus, Philosophical Transactions for 1793.)

5. Count Friedrich Hahn, of Remplin, Mecklenburg, saw the phenomenon unusually well and often during the spring and summer of 1793, in twilight as well as in daylight. He employed excellent instruments, and gives a very detailed description of what he saw; also two sketches. No other observer seems to have seen the phenomenon so often and so well. (Berliner astronomisches Jahrbuch für 1793, p. 188.)

6. The venerable old selenographer Schröter saw the phenomenon only once, February 14, 1806, in faint twilight, with an excellent telescope, and gives a very accurate description and sketch of it. He remarked an important feature in the phenomenon: the limb of the dark hemisphere was brighter than its central part. (Berliner astronomisches Jahrbuch für 1809, p. 164, and Beobachtungen des grossen Cometen von 1807, Appendix, p. 66.)

7. Simultaneously with Schröter, and independently of him, C. L. Harding, at Gottingen, succeeded in observing the dark side of Venus on three different evenings—January 24, February 28, and March 1, 1806. On the second of these days the light was reddish grey, and on all of them the phenomenon was seen with the utmost sharpness and distinctness. (Berliner Jahrbuch für 1809, p. 169.)

8. The well-known observer of the sun J. W. Pastorff, at Buchholz in Prussia, saw the phenomenon (as he reports) many times so distinctly that he could distinguish bright and dark patches in the faint grey light. Only one date and a corresponding drawing are given, February 10, 1822, at 5 P.M., when the breadth of the crescent was 0·23 diameter of the whole disk. (Berliner Jahrbuch fur 1825, p. 235.)

9. June 8, 1825, at 4 A.M., almost in full daylight, the phenomenon was witnessed by Gruithuisen at Munich. No particulars given. (Astronomisches Jahrbuch fur 1842, herausgegeben von Gruithuisen, p. 158.)

10. The next observation was made by Mr. Guthrie, near Bervie, N.B. (Great Britain), during the inferior conjunction in December 1842. Mr. Guthrie saw a narrow fringe of light around the whole disk of the planet. (Monthly Notices of the Roy. Astr. Soc., vol. xiv. p. 169.)

11. G. A. Jahn, at Leipzic, saw the dark side of Venus on September 27 and 28, 1855, at 11 A.M., in broad daylight. (Jahn's Unterhaltungen im Gebiete der Astronomie, vol. ix. p. 320.)

12. Mr. Berry, of Liverpool, saw the phenomenon on the evening of January 14, 1862. (Month. Not. vol. xxii. p. 158.)

13. Mr. C. L. Prince, of Uckfield, observed Venus almost daily during her inferior conjunction between Sept. 23rd and 30th, 1863, in bright daylight, and could trace on every day the whole disk, or at least a faint fringe of light around the edge. (Month. Not. vol. xxiv. p. 25.)

14. Mr. W. Engelmann, of the Leipzic Observatory, saw the phenomenon repeatedly—most advantageously, as it seems, on April 20, 1865, immediately after sunset. The dark side was greenish grey, a little brighter than the sky. (Astron. Nachr. No. 1526, vol. lxiv. p. 223.)

15. During the inferior conjunction of 1867 Venus was well observed by Professor C. S. Lyman, of Yale College, Newhaven, U. S. The extension of the crescent over more than 180° was seen during a period of eleven days: on 10th and 12th of December the ~~thin~~ bright crescent formed an unbroken ring; on the day of conjunction (11th December) the close proximity of the sun permitted no observation. (American Journal of Science, 2nd series, vol. xliii. p. 129.)

16. Mr. Th. Petty, of Deddington, near Oxford, saw the dark side of Venus

on May 23 and June 9, 1868, probably during twilight. (Astronomical Register, No. 68, p. 181.)

17. In the same year I was observing Venus attentively for some months, chiefly in broad daylight, with a small but good achromatic. I saw spots on different occasions; and on July 4, 1868, at 1 P.M., I could see traces of the dark disk, though unsteadiness of the air and insufficient optical power prevented me from becoming certain of what I saw.

18. On February 5, 1870, the dark side of the planet, then near inferior conjunction, was seen (in daylight, I suppose) by Mr. R. Langdon, of Silverton, Devonshire. (Month. Not. vol. xxxii. p. 307; Astron. Reg. No. 115, p. 163, where the year is erroneously stated to be 1872.)

19. Captain W. Noble, of Leyton, Essex, saw the dark part of Venus very distinctly on February 22, 1870, only twenty-four hours before conjunction, in close proximity to the sun. In a later communication, Captain Noble adds that he saw the dark side always darker than the surrounding sky, and that he rarely failed to see it whenever Venus was in or near inferior conjunction. (Month. Not. vol. xxx. p. 152; Astron. Reg. No. 88, p. 74, and No. 130, p. 258.)

20. At the meeting of the Royal Astronomical Society, March 11, 1870, Mr. Browning stated that, without any special contrivance, he could see all the globe of the planet in his 12-inch speculum—perhaps on twenty different evenings, as Mr. Browning told me orally, and always in bright twilight. The unillumined side appeared darker than the sky around it. (Ast. Reg. No. 88, p. 74, and No. 131, p. 281.)

21. On August 9, 1870, I was regarding Venus in bright sunshine at 11 A.M., when a lady who was with me at that time immediately perceived the whole disk of the planet. I showed to her Schroter's drawing, which she declared to be in perfect accordance with what she saw in the telescope. I fancied only at moments that I saw a faint line of light all round the greyish disk. Illumination unusually large (0·35); air much disturbed at the time.

22. Dr. A. Winnecke, of Karlsruhe, saw the phenomenon twice, on September 25, 1871, at noon, and November 6, 1871, at 5 A.M. (Astron. Nachr. No. 1863, and No. 1866, vol. lxxviii. pp. 236 & 287.)

On the day subsequent to Dr. Winnecke's first observation, September 26, Captain Noble could not make out the dark hemisphere so well seen by him a year before that time, but he adds that the sky was not clear. (Month. Not. vol. xxxii. p. 17.)

From the above conspectus it appears that the unillumined side of Venus has been seen by 22 different observers:—

In twilight by 13 (once by 4, many times by 9).
In daylight by 11 (once by 6, many times by 5).

4 observers saw a faint line of light encircling the dark disk, 19 of them saw the disk itself. Of the 22 cases reported, 12 have been observed during the last eleven years, say one per year; and I am disposed to think that the phenomenon is a normal one, and that with sufficient optical power and attention under a favourable sky it is to be seen at every inferior conjunction, though I would by no means advance that it is constantly visible, which would be a statement directly opposed to facts.

For the explanation of this remarkable phenomenon the following causes have been suggested:—

1. *Phosphorescence.*—This was the idea of Sir William Herschel, Harding, and partly of Schröter. It does not appear clearly whether they under-

stood the word in its modern sense, meaning substances which absorb sunlight and emit it in darkness without being chemically changed, or whether they included under that name, like all the elder physicists, slow combustions also, like that of phosphorus and rotten wood, which in modern terminology do not belong to true phosphorescence. In both cases it is difficult to imagine the whole surface of the planet to be covered with such substances as sulphide of strontium, diamond, phosphorus, or rotten wood.

2. *Auroral phenomena.*—This was partly Schröter's idea; it is supported by a most extraordinary observation of Mädler, who, during the whole evening of April 7, 1833, saw Venus surrounded by long bright immovable rays. Professor Zöllner, of Leipzic, strongly advocates this idea, and trusts that the spectroscope will reveal bright lines in the grey light of the unilluminated hemisphere of Venus.

3. *Proper light.*—An explication upheld by Pastorff, who supposed the atmosphere of the planet to be large and self-luminous. Possibly also the planet might still be incandescent, as is supposed to be the case of Jupiter by Mr. Nasmyth; but on this supposition the secondary light should be always visible, which is positively not the case.

4. *The light of the Earth.*—This, as seen from Venus, far exceeds the greatest brightness of Venus as seen by us; and according to the calculation of Dr. Rheinauer, of Munich (Grundzüge der Photometrie, 1861, pp. 58–77), the grey light of Venus, if resulting from this cause, should equal a star of the 14th magnitude. That this explanation is insufficient is so clear as to need no further proof.

5. *Negative visibility*, as it is called by Arago, or projection on the coronal light of the sun, as suggests Mr. Lynn (Astr. Reg. No. 109, p. 12) and, if I am right, Mr. Noble (Month. Not. vol. xxxii. p. 17). This explanation suits only those cases in which the unilluminated side of the planet was seen *darker* than the surrounding sky (Messrs. Browning and Noble), but not those of the majority of observers, who make it *brighter* than the sky.

6. *Accidental combustion and other illuminating processes.*—Gruithuisen suggests large luxuriant forests set on fire, an idea by no means absurd in itself; but, indulging in the fantastic cast of his mind, he brings it in connexion with general religious festivals of the inhabitants of Venus, a speculation in which it is not quite easy to follow the famous Munich selenographer. Immense prairies and jungles would do still better; but even these will hardly suffice for so frequent and general a phenomenon.

I will suggest another explanation, without laying too much stress on it, though perhaps it is not a mere fancy. The intense brightness of Venus, and particularly the dazzling splendour of her bright limb, is deemed by the late G. P. Bond and by Professor Zöllner, a competent authority in photometric matters, not to be explicable without assuming specular reflection on the surface of the planet. This Professor Zöllner supposes to be done by a general covering of water; and indeed if the faint grey spots of Venus, delineated in 1726 by Bianchini and rediscovered by Vico in 1838, are land, then nine tenths at least of the surface of Venus are covered by sea. Should Venus be in a geologically less advanced state, viz. less cooled than our globe, a supposition rendered not improbable by her considerable size and her nearness to the sun, then the present condition of Venus would be analogous to that of the earth in the Jurassic period, when large isolated islands were bathed by immense seas, blood-warm, and teeming with an abundance of animal life difficult to be conceived.

The intensity of the phosphorescence of the sea, shown not unfrequently by our tropical seas, gives us some idea of the intensity which this magnificent phenomenon could acquire under such unusual circumstances; and it is, I think, not unreasonable to expect that such a phosphorescence could be seen even at planetary distances. It would explain the fact that the edge of the dark hemisphere of Venus is seen brighter than its central part; for it is demonstrable by calculation and confirmed by observation (as in the case of the sea near the horizon, or the edge of the full moon), that a rough surface emitting diffused light is seen the brighter the more obliquely it is regarded.

It is satisfactory to think that my suggestion can be put to the test of physical inquiry. M. Pasteur found the spectrum of cucuyos (tropical phosphorescent beetles) a continuous one; and, according to Mr. Piazzi Smyth, the same holds good for the phosphorescent animalculæ of the sea (Month. Not. vol. xxxii. p. 277), so that the spectroscope will be able to decide between Professor Zöllner's hypothesis and mine.

Since the foregoing note was read before the British Association, Dr. H. Vogel has published observations of Venus with the large refractor of Baron Bülow (Beobachtungen auf der Sternwarte zu Bothkamp, Heft 2, pp. 118–132). He saw the secondary light of Venus on seven mornings between October 15 and November 12, 1871, in bright twilight. The light was yellowish, faint, brighter near the terminator, fading away on the other side, and never extended over more than 30° of arc on Venus. On five other mornings nothing was seen.

Report of the Committee, consisting of Dr. Rolleston, Dr. Sclater, Dr. Anton Dohrn, Professor Huxley, Professor Wyville Thomson, *and* E. Ray Lankester, *for the foundation of Zoological Stations in different parts of the Globe. Drawn up by* Anton Dohrn, *Secretary.*

The Committee beg to report that since the last Meeting the building of the Zoological Station at Naples has been completed. [A photograph of the building was exhibited at the Meeting when the Report was read.]

The internal, mechanical, and scientific arrangements require two months for completion; and though the cost of the whole has exceeded the estimates in no small degree, Dr. Dohrn hopes nevertheless to balance them by finding new means of income for the establishment. He has succeeded in obtaining a subsidy of £1500 from the German Empire, and his scheme of letting working-tables in the laboratories of the station has met with general approval. *Two* tables have been let to Prussia and *two* to Italy, *one* to Bavaria, *one* to Baden, and *one* to the University of Strasburg; a letter from the Dutch Ministry of the Interior informs Dr. Dohrn that Holland accepts the offer of one table for the stipulated annual payment of £75; and, moreover, Dr. Dohrn has been informed that the University of Cambridge intends to hire one table for three years. Applications have also been made to the Imperial Government of Russia, both on the part of Dr. Dohrn and by different Russian scientific authorities. A correspondence has taken place between Dr. Dohrn and Professors Lovén and Steenstrup about a possible participation

of the Scandinavian kingdoms, but has as yet led to no definite result. The case with respect to Switzerland and Saxony has been similar; but hopes are entertained that these countries may join the others in their endeavour to support the Zoological Station, and to afford every facility to their naturalists of profiting by this new and powerful instrument of investigation.

Dr. Dohrn thinks it desirable to explain once more the leading ideas that have induced him to request the assistance of all these Governments and Universities.

The Zoological Station has sprung up altogether in consequence of the desire to facilitate investigation in marine zoology, and to enable naturalists to pursue their studies in the most effective manner and with the greatest possible economy of money, time, and energy. All zoologists who have visited Naples during the last year (amongst whom have been Professors Gegenbaur, Claus, Oscar Schmidt, and Pagenstächer) consider that this end will be fully attained by the organization and arrangements made or intended to be made in the station. They all agree that it is in the highest degree desirable that nobody who cares at all for the progress of zoology should fail to join Dr. Dohrn's exertions in bringing about a universal participation in the expense of keeping up the new establishment; and thus it is due to Professor Oscar Schmidt's influence that the Imperial Government at Berlin have hired a table for the University of Strasburg, and to the initiative of Professor Pagenstacher that the Grand Duchy of Baden has also taken one table, whilst Professor Claus has promised his best services to induce the Austrian Government to take a similar step.

As is, we believe, universally known, no money-speculation whatever is contemplated by the founder of the Naples Station, in so far as money speculation means a high interest and the return of the capital invested into the pocket of the founder. Nevertheless, every honest means will be used to procure as large an income as possible, for more than one reason. There is not only the necessity incumbent upon the establishment to repay some of the capital to those who have lent money to Dr. Dohrn, in order that he might complete the building in its actual enlarged state (a task for which his own means would not have sufficed in spite of the German Government's subsidy), but, further, there must be provided reserve-funds for the eventuality that the income of the aquarium may not cover the outlay for the year's management, thus causing a sudden stand-still of the establishment: and last, but not least, it is intended to have every year a certain sum to spend for scientific pursuits. If, for instance, Professor du Bois Reymond, as he has expressed to Dr. Dohrn his wish to do, should proceed to Naples to carry on experiments on the electric *Torpedo*, it would require no inconsiderable means to buy the necessary apparatus and physiological instruments, and to provide this famous physiologist every day with fresh material to conduct his investigations on a scale large enough to yield a distinct result. Or to enable embryologists to carry on an investigation on Comparative *Selachian* embryology, it would be necessary to buy large quantities of female sharks and skates, which are by no means so cheap as a foreigner might think. And for conducting researches well and accurately, every naturalist knows what an amount of money must be spent in dredging-expeditions, how much trouble, how much time and work are necessary to get at the animals and to determine their identity or non-identity with the known and described species. And this is one of the foremost duties which the Zoological Station will propose to itself, as it is too well known how great a confusion exists with regard to systematic and zoological questions of the Mediterranean

fauna. To bring this confusion to an end, it will require more than one lustrum and more than one thousand pounds. There may perhaps have risen a prejudice among Systematists against the new establishment, as one which, in consequence of the partiality of its leader for Darwinian views, might dispense altogether with Systematists. Nothing could be more erroneous than such an opinion. The leader of the Zoological Station is as little opposed to Systematists as the Darwinian theory itself. He is of opinion that zoological battles may be best won, according to Count Moltke's principle, "by marching separately and fighting conjunctively," thus leaving to Systematists their own route, as well as to anatomists, physiologists, and embryologists, on condition only that they will, when meeting the enemy (Error and Ignorance), fight together; and he desires the Zoological Station to become such a battle-field, where all the different zoological armies may meet and fight their common adversaries.

That such wars need much of the one element, which, according to Montecuculi, best secures victory, "money, money, money," will be illustrated by two letters, which Dr. Dohrn has received from Professor Louis Agassiz, and which he has been authorized to publish.

The celebrated American naturalist writes, under the date "Museum of Comparative Zoology, Cambridge, Mass., 10 June, 1873," the following:—

"It is a great pleasure and satisfaction to me that I can tell you how, in consequence of the munificence of a wealthy New York merchant, it has become my duty to erect an establishment whose main object will be similar to that of your Naples Station, only that teaching is to be united with it. The thing came thus to pass:—During last winter I applied to our State authorities to secure more means for the Museum in Cambridge (Mass.). Among the reasons I alluded to the necessity of having greater means for teaching purposes. I addressed my speech to our deputy, and it was afterwards reported in the newspapers. By chance the report fell into the hands of a rich and magnanimous tobacco-manufacturer, Mr. John Anderson, of New York. He sent on the same day a telegram, asking me whether I would be at home the following day in order to meet two friends: to which I answered, Yes! The two gentlemen came by order of Mr. Anderson, offering me a pretty island in Buzzard Bay for the purpose of erecting a zoological school. I accepted this offer, of course, but added that without further pecuniary means it would be difficult to teach there. After two days a sum of 50,000 dollars was handed over to me; and now I am erecting there a school for Natural History, which at the same time will be, as a Zoological Station in the immediate neighbourhood of the Gulf-stream, of the greatest assistance to our zoologists, especially as splendid dredging-ground exists there. This certainly must greatly promote zoological study in the United States. Already forty teachers of our normal and high schools have applied for this summer's lessons; besides, I shall be accompanied by my private students.

"Some of my colleagues are ready to assist me, so that I may hope to obtain already some results before winter's approach."

The next letter is dated "Penikese, August 13th, 1873," and contains some more information.

"The school was opened on the 8th of July. Some of my friends have assisted me as teachers; several other naturalists are occupied with special studies; the bottom of the sea is very rich, the general situation quite excellent. The solitude which prevails is a great help for our teaching purposes. As students, forty teachers of our public schools are present, besides ten younger gentlemen, who are preparing for a scientific career.

"The buildings are very well constructed and adapted to their uses. The two chief houses have a length of 120 feet, and a breadth of 25 feet each. In the lower story are the laboratories, each with 28 windows; every student occupies one window, and has for himself one aquarium. In the upper story of each house are twenty-eight bedrooms, one for every student. The professors and naturalists are lodged in another house of the shape of a Greek cross. The dining-room is in a third house, which contains also the kitchen and the servant-rooms. Besides, we have an ice-house, a cellar for alcohol, stables for domestic animals; about one hundred sheep are feeding in the pasture-grounds of the island; some smaller hutches contain rabbits, guineapigs, &c.

"Next year physical, chemical, and physiological laboratories will be constructed.

". . . . I believe I did not tell you before that my son-in-law presented me on my birthday with 100,000 dollars for the enlargement of the Museum; I intend to apply this sum chiefly to the augmentation of the collections, hoping the State will pay for the adequate enlargement of the buildings . . ."

These letters prove that the name of this Committee has not been ill-chosen; for though the American Zoological Station has not been founded by its direct intervention, there can be little doubt that the foundation of the Zoological Station at Naples has been the signal for a new and powerful movement to assist zoological research.

Of course the American station has met with such extraordinary advantages that a competition between it and the Naples Station, as regards means and favourable circumstances, would be all but hopeless for the latter. Nevertheless it may prove a powerful instrument in carrying out strictly the self-supporting principle, by earning money through the aquarium, and by letting tables in the laboratory. And though any act of munificence to the Naples Station is exceedingly desirable and would be heartily welcomed (as the moment has not yet arrived when any scientific establishment in this world has at its disposal more money than it can spend), the greatest stress will always be laid upon these two elements.

The Reporter is further glad to state that the library of the Zoological Station has constantly been augmented. A magnificent gift has been made by the Zoological Society of London, which has presented a complete set of its illustrated 'Proceedings.' The Royal Academies of Copenhagen, Naples, and Berlin have also granted their biological publications, and promised to continue to do so in future. The Senckenberg Institute in Frankfort-on-the-Main, as well as the Zoological Garden of that city, have sent all their Transactions; so has the Smithsonian Institution in Washington with respect to its biological publications. Well-founded hopes are entertained that in a short time many other Academies and scientific Societies will follow the example of those above mentioned.

German publishers have continued to send their biological publications gratis to the library of the Station; and great quantities of books, pamphlets, and publications, in separate form, of papers published in periodicals have been forwarded from all parts of the scientific world through the kindness of the authors.

On the part of the Zoological Station, though still in an embryonic state, considerable activity has been displayed with regard to furnishing continental zoologists with collections of well-preserved marine animals. Thus, Prof. Wilhelm Müller, indeed, has been supplied with *Amphioxus* and Tunicata, Prof. Greeff, of Marburg, with large quantities of Echinodermata; mixed collections of every kind of animals have been sent to Prof. Oscar Schmidt,

Strasburg, Professor Claus, Vienna, to the Senckenberg Museum at Frankfort, the Natural-History Society at Offenbach, and many others.

Several German zoologists have already announced their intention to come during next winter and work in the Station: a similar announcement is made from an Italian zoologist and from Dr. M. Foster; and I am informed that two young English biologists will arrive at the Station in January.

The Committee hope this Report will convince the Association that the year between their present and last Meeting has been one of steady and considerable progress for the Zoological Station at Naples. The Committee refrain from making any further proposition to the Association, but express their wish that every influence may be used to secure to the Station at Naples such assistance as will serve to promote the eminent scientific ends for which it has been erected.

Second Report of the Committee, consisting of Professor HARKNESS, WILLIAM JOLLY, *and* Dr. JAMES BRYCE, *appointed for the purpose of collecting Fossils from localities of difficult access in North-Western Scotland. Drawn up by* WILLIAM JOLLY, *Secretary.*

DURING the past year search has been made for fossils at various points along the great limestone strike of the N.W. Highlands, but, with the exception of the Durness basin, from which the fossils already collected have been alone obtained, none have been found at any new locality. The lessee of the lime-kilns of Loch Eribol has been obliged to give them up. This the Committee have to regret on their own account, as, from his interest in the subject, they anticipated good results from the intelligent search he was making in the large development of limestone in that interesting locality, which till now has continued barren of organic forms. Special search has been made by two teachers in the limestone at Inchnadamph on Loch Assynt, but as yet without success. The Committee have not been fortunate enough to find any thing in this locality, except one piece found by the Secretary, which it is hoped may prove to be organic.

None of the Committee have this year found it possible to prosecute the search in person; but this continues to be done by several gentlemen resident in the district, whose services they have been fortunate in securing.

The Committee have, during the last two years, gathered a considerable number of specimens. These fossils, with those obtained for Professor Nicol of Aberdeen, and deposited in the College Museum there, they think it important that the Association should have carefully examined by an adept in fossil remains, in order to lead to more certain determination of the age and place of these North-western rocks in the geologic series. They think, however, that this examination should not be made till a larger collection has been obtained. As the discovery of fossils at other localities than Durness is most desirable, especially in order to determine if the fossiliferous Durness limestone is the same as that in the line of the great strike from Eribol to Skye, they are anxious that the search should still be prosecuted in these hitherto barren localities. The Committee would therefore propose their reappointment by the Association for this purpose.

Fifth Report of the Committee on the Treatment and Utilization of Sewage, consisting of RICHARD B. GRANTHAM, *C.E., F.G.S.* (Chairman), F. J. BRAMWELL, *C.E., F.R.S.*, Professor W. H. CORFIELD, *M.A., M.D.* (Oxon.), *J. BAILEY DENTON, *C.E., F.G.S.*, J. H. GILBERT, *Ph.D., F.R.S., F.C.S.*, W. HOPE, *V.C.*, Professor A. W. WILLIAMSON, *Ph.D., F.R.S., F.C.S.*, and *Professor J. T. WAY.

N.B.—Those members whose names have an asterisk prefixed have not attended any meeting of the Commitee during the year.

THE Committee, in presenting its Fifth Report, has to state that it has continued that part of the inquiry for which it was more particularly reappointed, viz. the examination of the typical case of sewage-farming at Breton's Farm near Romford; and similar Tables to those furnished last year are again supplied, and are described in the portion of this Report referring to this subject.

Another analysis has also been made of the soil of the farm, showing a considerable increase in the amount of nitrogen and of phosphoric acid contained in it.

A further examination has also been made of the sewage-farm at Earlswood, with more satisfactory results than on previous occasions; and Dr. Gilbert has again furnished a note on the dry earth system, which he has made a subject of special investigation.

Whitthread's process, which was described in last year's Report, and of which a short account will be found in the subjoined abstract, has been for a few days at work on a considerable scale at Enfield. A member of the Committee, who recently inspected what was going on there, states that an excellent opportunity for further investigation will now be afforded.

It has been considered advisable at this time, when the Committee has (within a few pounds) exhausted its funds, to prepare and present with this Report an abstract of the four previous Reports made by it to the British Association; this has been done by Professor Corfield on its behalf, and the abstract will be found in another part of this Report.

Since the Committee's last Report the Local Government Board has presented to Parliament a Return moved for in the House of Commons, dated May 13th, 1873, and entitled a "Return of the names of Boroughs, Local Boards, Parishes, and Special Drainage Districts which have, through loans, provided Sewage-Farms or other means for the Disposal of Sewage by Filtration or Precipitation." The various Tables contained in this Return profess to give information, which, so far as it goes, would be valuable if exact. One radical error in the scheme of the Tables is, that there is no separation of the capital expenditure and working expenses of the year, while in the case of sewage-farms the cost of purchasing land is not separated from that of works.

SECTION I.—*Additional Note on the Dry Earth System.*

In former Reports the Committee has given the results obtained by Dr. Gilbert on the determination of the nitrogen in the soil which had been used in a Moule's earth-closet once, twice, and three times. The same soil, after passing through the closet the fourth time, has been again examined, and the results of the series of determinations are given below:—

	Before used.	After using once.	After using twice.	After using three times.	After using four times.
Percentage of nitrogen in soil dried at 100° C.	0·073	0·240	0·383	0·446	0·540

In the air-dried condition the soil, even after being used four times, contained less than a half per cent. of nitrogen, and, as the Table shows, only 0·54 per cent. in the fully dried condition. Thus, after passing through the closet four times, the soil was but little richer than a good garden-mould; and the Committee must still say, "that such a manure, even if disposed of free of charge, would bear carriage to a very short distance only."

The Committee would refer to former Reports for its opinion of the system in other aspects than that of the mere manurial value of the product; and its conclusions will be found summarized further on.

Section II.—*Earlswood Sewage-Farm.*

The Committee paid another visit to this farm on the 17th May, 1873, and found that nearly the whole of the land was occupied by Italian ryegrass, except about one acre which had been planted with potatoes. There was a very small sale for the ryegrass when green, so that it had been made into hay and stacked; some of last year's stacks still remained on the ground; this shows the necessity of growing crops suited to the neighbouring markets, or else of keeping live stock to consume them, and more particularly cows, for which Italian ryegrass and similar forage crops (grown by means of properly conducted sewage-irrigation, and periodically cut and carried to the stalls) are especially suitable.

At the above date the first crop of ryegrass was only just being cut, whereas the third or fourth crop ought to have been ready, and would have been on a thoroughly drained, properly laid out, and systematically managed sewage-farm.

Samples were collected of the effluent water as it flowed in a ditch, on its way to the river Mole, about half a mile from the farm; and the results of analysis showed that the sewage was much more satisfactorily purified during the dry summer of 1873 than during the wet one of 1871, when the land was supersaturated.

In former Reports of the Committee attention was drawn to this farm, which was then receiving the sewage of Red Hill; it was intended that the sewage of the town of Reigate should also be conducted to this farm, but the works for this purpose are not yet completed.

Analysis.

N.B.—Samples taken twice a day, in the proportion of $\frac{1}{1000}$ of the flow per minute. Results given in parts per 100,000.

Dates (inclusive).	Description of samples.	Average rate of flow per minute.	Solid Matter. In solution. Dried at 100° C.	Solid Matter. In solution. After ignition.	Solid Matter. In suspension. Dried at 120° C.	Solid Matter. In suspension. After ignition.	Chlorine.	Nitrogen. In solution. As ammonia.	Nitrogen. In solution. Organic.	Nitrogen. In solution. As nitrates and nitrites.	Nitrogen. In solution. Total.	Nitrogen. In suspension.	Nitrogen. Total in solution and suspension.
1873. From 16th June, to 5th July.	Effluent water from Earlswood Sewage-farm ..	galls. 270	36·10	24·90	...	.	4·93	0·008	0·155	0·96	1·123	...	1·123

SECTION III.—*Breton's Farm, Romford.*

The systematic observations hitherto carried on with regard to this farm (for a record of which see previous Reports and the following abstract) have been continued during the past year, and the form of last year's Tables has been again adopted to set out the results arrived at.

	tons.
The quantity of sewage received from the town of Romford into the tanks and pumped on to land from March 25th, 1872, to March 24th, 1873 (inclusive), is according to the gaugings..	405,443
The quantity of effluent water repumped on to land during the same period is..	38,671
The total quantity of *diluted* sewage *pumped* for distribution is therefore	444,114
The quantity of sewage received from the town of Romford and distributed on to land by gravitation during the above period is	74,499
The quantity of effluent water distributed on to land by gravitation during the same period is	8,980
Therefore the total quantity of sewage, diluted sewage, or effluent water which we have to account for is	527,593

Accounted for thus :—

As appears by the cropping Table the quantity of sewage applied to the land is	523,810 tons.
Supplied to Mr. Gooch (adjoining farmer)	1,548
Applied to garden........................	2,235
Total....	527,593

Tables I. & II. are continuations of the Tables of last year bearing the same numbers, and are records of the observations made with regard to the quantity and composition of the sewage and the effluent water. From the organic nitrogen column in Table II., referring to the effluent water, it will be seen that an improvement has taken place, due probably to the solidifying of the earth over the drains; the proportions of total nitrogen in the effluent water for the two years show a difference of only 0·01 in 100,000 parts.

Table III. shows the absolute quantities of nitrogen contained in the sewage and in the effluent water, as calculated from the details summarized in Tables I. and II.

From this it will be seen that the volume of sewage distributed was considerably greater than in the previous year; but the proportion of nitrogen was smaller, indicating a greater dilution due to the large increase in rainfall.

It would appear that the total amount of nitrogen distributed on the farm was 26·9814 tons, while the previous year's total would appear from the Table to have been only 21·0245 tons; but the explanation is that during the previous year a large quantity of undiluted sewage, namely 83,962 tons, "was run upon a plot of land at the lower part of the farm by gravitation, and simply filtered during periods when it could not be put on the farm, owing to further drainage-works being in progress." The amount of nitrogen which must be added to last year's total to make it comparable with this year's is 6·1964 tons, which makes 27·2209 tons, or practically the same quantity as this year.

The quantity of effluent water measured was 470,552 tons as against only 195,536 tons last year. This is to be accounted for partly by the greater dilution by rain, indicated by a difference of 0·01 of nitrogen per 100,000 parts in the composition of the effluent water, but principally by the fact that the extra drainage alluded to in the last Report has been carried out. Although, therefore, the effluent water this year shows less total nitrogen per 100,000 parts, yet the absolute quantity contained in it amounted to $\frac{1}{5}$ instead of $\frac{1}{10}$ of the absolute quantity distributed over the farm.

Tables IV. to VI. are similar to the corresponding Tables of last year, and are subject to the same qualifications with regard to the quantities of sewage applied to the various crops and plots; that is to say, that the means available for the measurement of the quantities of sewage and effluent water only rendered possible the actual measurement of the total daily quantities, the details professing to show approximately the quantities applied to the individual crops and plots being merely calculated numbers obtained from the daily totals by breaking these up in proportion to the areas irrigated each day. The chief value of these figures is to show the desirability of obtaining such details with precision. This, however, would require a numerous staff of trained chemical and engineering assistants, and also the expenditure of a considerable sum of money in apparatus, and in isolating, by means of sunken barriers of concrete, the individual plots.

By comparing Tables V. and VI. of this year with Tables V. and VI. of last year, it will be found that the total produce *taken off* the farm during the year ending March 24th, 1873, was 1704 tons against 2714 for the preceding year. This was due partly to the fact that the area in standing crop on March 24th, 1873, was 87·62 acres against 40·49 acres on March 24th, 1872 (see Table VII.), and partly to the fact that there were 26·18 acres of cereals in the year now recorded, against 0·9 of an acre in the previous year.

The nitrogen recovered in the crops taken off the land for the year under review is estimated at 15,704 lbs. as against 19,667 lbs. for the preceding year. This smaller quantity recovered out of a larger quantity applied is obviously due to the same causes which affected the weight of crops.

The nitrogen escaping in the effluent water is estimated at 11,973 lbs., as against 5024 lbs. in the previous year. This increase is due to the additional drainage of the farm giving a larger *measured* quantity of effluent water as before explained, namely 470,552 tons as against 195,536 tons.

The amount of nitrogen unaccounted for (that is to say, accumulated in the standing crops and top soil, washed into the subsoil, or lost) is the difference between that applied in the sewage (60,438 lbs.) and the sum of the quantities recovered in the crops (15,704 lbs.) and escaping in the effluent water (11,973 lbs.)—namely, 32,761 lbs., as against 22,404 lbs. unaccounted for in the previous year.

These quantities, expressed in percentages, show that of every 100 parts of nitrogen distributed over the farm in the sewage, 26 were recovered and taken off the farm in crops, 20 escaped in the effluent water, and 54 remained in the standing crops, in the soil, or in the subsoil, or were lost.

This nitrogen balance-sheet shows that the results of an experiment in agricultural chemistry over so extended an area, and with so great a variety of crops, can only give true averages if conducted over a lengthened series of years; for the produce of the farm was in many respects more satisfactory in the year now recorded than in the preceding one, having regard to the amount of cereals grown and the crops left standing, and yet at first sight it appears the reverse.

In the Report of the Committee presented at Liverpool it was stated, on the authority of information furnished by the local authorities, that

(1) The population of Romford was "about 8000;"
(2) That the refuse of about 7000 persons was discharged entirely into the sewers;
(3) That the whole population is within the area provided with underground sewers.

As the Committee had some doubts as to the correctness of these statements, it was thought advisable to have a census of the town, with particulars of sewage connexions, &c. made, and the results will be found in Table VIII.

Samples of soil were very carefully taken on April 30th, 1873, in presence of Messrs. Corfield, Gilbert, Grantham, Hope, and Williamson, at the same part of the farm as on the previous occasion (July 15th, 1870), when no sewage had been applied to that part of the farm. These samples were mixed, and an average sample was analyzed by Dr. Russell with the following results:—

Examination of Soil from Breton's Farm, Sample taken April 30th, 1873.

Soil, after drying by exposure to the air, consists of, in 100 parts:—

Stones too large to pass through holes of a sieve 3·88 millims.	35·77
Moisture driven off at 100° C.	3·40
Soil passing through sieve	60·83
	100·00

In 100 parts of the original soil there is:—

Insoluble in strong hydrochloric acid	55·02
Loss on ignition (includes water driven off at 100° C.)	6·65
Phosphoric Acid ($P^2 O^5$)	0·058
Chlorine	0·002
Ammonia	0·016
Nitrogen as Nitrates &c.	0·00029

The second part of the above Table represents the percentage amounts (calculated from the original soil) of the more important constituents of the 64·23 parts of undried soil. Comparing these results with those given in the Committee's Second Report, it will be seen that the phosphoric acid in the soil has increased from 0·01 to 0·058 per cent., that the loss on ignition of the soil is much greater (leaving water out of the question), that the amount of ammonia has been increased from an inappreciable quantity to 0·016 per cent., and that the amount of nitrates has been also increased. The amount of total nitrogen in the 64·23 parts of soil was estimated by the soda-lime process with the following result:—

Total Nitrogen determined by the Soda-lime Process.

1st experiment	0·191 per cent. Nitrogen.
2nd experiment	0·187 " "
Mean	0·189 per cent. Nitrogen

in soil without stones; therefore in original soil (stones included) =0·121 per cent. Nitrogen.

There is therefore no doubt that the quality of the soil has been considerably improved by the sewaging, and that a good deal, both of the nitrogen and phosphoric acid, is retained in it.

TABLE I.—*Breton's*

Statement of Weekly Quantities of Sewage received on the Farm, with the propor-
escaping from the Drains, with the proportions repumped, distributed by gravi-

[Continued from

Number of weekly return.	Date (inclusive).	Average noonday temperature.	Rainfall during week.	Town sewage. Total delivered on farm.	Town sewage. Average temperature thereof.	Town sewage. Quantity pumped.	Town sewage. Quantity distributed by gravitation.	Total quantity returned from land
	1872.	° F.	in.	galls.	° F.	galls.	galls.	galls.
110.	July 14 to July 20	67	0·89	1,690,100	65·5	1,383,700	306,400	2,198,200
111.	July 20 to July 27	80	0·48	1,653,800	68·7	1,653,800	......	1,856,900
112.	July 28 to Aug. 3	69	0·76	1,677,100	67	1,677,100	....	1,704,000
113.	Aug. 4 to Aug. 10	65	1·64	1,858,700	65	1,060,100	798,600	1,852,100
114.	Aug. 11 to Aug. 17	67	0·01	1,582,000	65	1,582,000	......	1,081,000
115.	Aug. 18 to Aug. 24	70	0·00	1,358,400	66	1,358,400	......	1,348,600
116.	Aug. 25 to Aug. 31	67	0·89	1,533,300	64·5	1,533,300	......	1,896,200
117.	Sept. 1 to Sept. 7	73	0·47	1,647,500	66	1,647,500	......	1,663,100
118.	Sept. 8 to Sept. 14	69	0·03	1,480,500	66	1,480,500	......	1,664,800
119.	Sept. 15 to Sept. 21	60	0·00	1,321,000	65	1,046,800	274,200	1,933,900
120.	Sept. 22 to Sept. 28	54	0·80	1,390,900	62	759,700	631,200	1,092,000
121.	Sept. 29 to Oct. 5	58	0·96	1,626,200	63	1,406,000	220,200	1,809,200
122.	Oct. 6 to Oct. 12	52	0·54	1,347,100	63	1,188,100	159,000	1,653,100
123.	Oct. 13 to Oct. 19	49	0·28	1,447,700	61	1,297,700	150,000	1,647,500
124.	Oct. 20 to Oct. 26	48	1·88	1,892,300	58	1,892,300	......	2,803,800
125.	Oct. 27 to Nov. 2	53	0·86	1,625,700	58	1,558,200	67,500	3,064,900
126.	Nov. 3 to Nov. 9	53	0·46	1,673,200	58	1,673,200	......	2,584,800
127.	Nov. 10 to Nov. 16	40	0·99	2,150,100	55	2,150,100	......	2,153,100
128.	Nov. 17 to Nov. 23	46	0·55	2,199,400	55	2,199,400	......	2,468,100
129.	Nov. 23 to Nov. 30	49·5	0·75	2,104,800	56	2,104,800	......	2,141,100
130.	Dec. 1 to Dec. 7	42	1·27	2,873,400	53	2,123,400	750,000	2,609,800
131.	Dec. 8 to Dec. 15	39	0·60	2,524,100	52	2,524,100	......	2,482,400
132.	Dec. 15 to Dec. 21	42	1·67	3,161,200	50	1,836,100	1,325,000	3,153,100
133.	Dec. 22 to Dec. 28	48·5	0·25	2,591,300	52	2,271,300	320,000	2,488,500
	1872. 1873.							
134.	Dec. 29 to Jan. 4	46·5	0·71	2,789,400	52.5	2,789,400	......	2,674,800
135.	Jan. 5 to Jan. 11	49·5	0·66	3,126,800	52	2,941,900	184,400	2,695,100
136.	Jan. 12 to Jan. 18	49	0·18	2,836,200	53	2,836,200	......	2,659,400
137.	Jan. 19 to Jan. 25	38	0·62	2,535,300	52	1,585,300	950,000	2,334,600
138.	Jan. 26 to Feb. 1	34	0·00	2,409,100	51·5	2,325,300	83,800	2,519,800
139.	Feb. 2 to Feb. 8	34	0·49	2,424,100	50	2,274,100	150,000	2,273,000
140.	Feb. 9 to Feb. 15	38	0·11	2,289,500	50	2,289,500	......	2,324,000
141.	Feb. 16 to Feb. 22	35	0·00	2,192,800	35	2,192,800	......	2,071,600
142.	Feb. 23 to Mar. 1	37·5	1·46	3,165,500	49	1,814,000	1,351,500	2,308,300
143.	Mar. 2 to Mar. 8	47·5	0·38	2,401,100	49	2,348,600	52,500	2,313,000
144.	Mar. 9 to Mar. 15	41·5	0·28	2,510,400	50·5	2,025,400	485,000	2,407,400
145.	Mar. 16 to Mar. 22	42	0·39	2,426,200	50	1,341,600	1,084,600	2,024,800
146.	Mar. 23 to Mar. 29	52·5	0·02	2,141,100	52	1,343,300	797,800	1,524,800

Sewage-Farm.

tions pumped or flowing by gravitation on to the Land, and of Effluent Water tation, or discharged into the River, and of the Total Liquid applied to the Land.

last Report.]

Effluent water.				Total liquid applied.					
Average temperature thereof.	Quantity repumped on to land.	Quantity distributed by gravitation.	Quantity discharged into river	Diluted sewage from tank.	Average temperature thereof.	Town sewage distributed by gravitation	Effluent water distributed by gravitation.	Total.	Proportion of effluent water to sewage distributed.
° F.	galls.	galls.	galls.	galls.	° F.	galls.	galls.	galls.	
59	133,700	64,800	1,999,700	1,353,500	65·5	306,400	64,800	1,724,700	1·275
62	97,700	......	1,759,200	1,724,300	68·0	......	......	1,724,300	1·077
62	600,200	......	1,103,800	2,204,700	66	......	......	2,204,700	·773
61	80,700	59,700	1,711,700	1,230,300	64·5	798,600	59,700	2,088,600	·887
61	134,400	......	946,600	1,673,000	65	......	......	1,673,000	·646
61	525,400	......	823,200	1,843,600	65·5	......	......	1,843,600	·732
61	192,500	......	1,703,700	1,752,200	64·	......	......	1,752,200	1·082
61	15,100	......	1,648,000	1,682,600	65·5	......	......	1,682,600	·988
62	574,300	......	1,090,500	1,977,900	65	......	......	1,977,900	·842
61	841,400	97,500	995,000	1,986,400	64	274,200	97,500	2,358,100	·820
58	169,900	127,100	795,000	1,001,800	61	631,200	127,100	1,760,100	·620
57	231,100	4,800	1,573,300	1,563,600	61	220,200	4,800	1,788,600	1·012
55	151,900	10,500	1,490,700	1,398,400	61	159,000	10,500	1,567,900	1·054
53	159,400	......	1,488,100	1,368,000	58	150,000	......	1,518,000	1·085
53	280,300	......	2,523,500	2,010,300	56	......	......	2,510,300	1·395
53	34,600	13,500	3,016,800	1,789,500	57	67,500	13,500	1,870,500	1·638
53	......	......	2,584,800	1,685,000	53	......	......	1,685,000	1·534
50	......	......	2,153,100	1,944,400	52	......	......	1,944,400	1·107
50	......	......	2,468,100	2,371,500	52·5	......	......	2,371,500	1·041
49	......	......	2,141,100	2,090,900	54	......	......	2,090,900	1·024
49	......	......	2,609,800	2,151,100	52	750,000	......	2,901,100	·900
49	......	......	2,482,400	2,460,200	50	......	......	2,460,200	1·009
48	......	135,000	3,018,100	1,731,800	50	1,325,100	135,000	3,191,900	·988
47	......	61,900	2,426,600	2,326,300	51	320,000	61,900	2,708,200	·919
47	......	......	2,674,800	2,750,800	51·5	......	......	2,750,800	·972
47	......	18,000	2,677,100	2,799,800	51	184,400	18,000	3,002,200	·898
48	......	......	2,659,400	2,958,800	52	......	......	2,958,800	·899
46	......	271,500	2,063,100	1,842,600	51	950,000	271,500	3,064,100	·762
43	......	......	2,519,800	2,159,100	49	83,800	......	2,242,900	1·123
43	......	......	2,273,000	2,278,100	48	150,000	......	2,428,100	·936
42	......	......	2,324,000	2,318,000	49	......	......	2,318,000	1·003
42	......	......	2,071,600	2,228,800	49	......	......	2,228,800	·929
42	......	208,500	2,099,800	1,767,300	48	1,351,500	208,500	3,327,300	·691
43	......	......	2,313,000	2,367,300	49	52,500	......	2,419,800	·956
43	......	46,700	2,360,700	2,287,300	48	485,000	46,700	2,819,000	·854
43	......	51,600	1,973,200	1,151,500	49	1,084,600	51,600	2,287,700	·885
44	59,300	58,400	1,407,100	1,362,800	52	797,800	58,400	2,219,000	·687

TABLE II.—*Breton's Sewage-Farm.*

Statement showing the Nitrogen according to analysis of Sewage as pumped and of Effluent Drainage-water, from March 1872 to March 1873.

Results given in parts per 100,000.

Analysis number.	Dates.	Sewage as pumped.						Drains.	Effluent drainage-water.					
		Nitrogen.							Nitrogen.					
		In solution.							In solution.					
		As ammonia.	Organic.	As nitrates and nitrites.	Total.	In suspension.	Total in solution and suspension		As ammonia.	Organic.	As nitrates and nitrites.	Total.	In suspension.	Total in solution and suspension.
	1872.													
20.	Mar. 18 to Mar. 23	4·54	0·88	......	5·42	1·14	6·56	Average of three.	0·114	0·12	1·46	1·70	......	1·70
21.	April 9 to April 13	3·43	0·30	......	3·73	2·67	6·40	,,	0·055	0·03	1·74	1·83	......	1·83
22.	May 13 to May 18	1·62	1·50	......	3·12	0·91	4·03	,,	0·044	0·30	0·26	0·60	......	0·60
23.	June 10 to June 15	1·88	0·87	......	2·75	1·27	4·02	,,	0·054	0·09	0·77	0·91	......	0·91
24.	July 8 to July 13	2·52	c·33	......	2·85	1·11	3·96	,,	0·021	0·13	0·85	1·00	......	1·00
25.	Aug. 5 to Aug. 10	......	......	......	2·87	3·36	6·23	,,	0·104	0·24	0·61	0·95	......	0·95
26.	Sept. 2 to Sept. 7	3·02	0·88	......	3·90	2·64	6·54	,,	0·255	0·28	0·14	0·67	......	0·67
27.	Sept. 30 to Oct. 5	2·50	1·82	......	4·32	0·82	5·14	Average of five.	0·075	0·275	1·09	1·44	......	1·44
28.	Oct. 28 to Nov. 2	3·17	0·97	......	4·14	0·93	5·07	,,	0·019	0·18	1·02	1·22	......	1·22
29.	Nov. 25 to Nov. 30	3·02	1·49	......	4·51	2·08	6·59	,,	0·063	0·137	1·14	1·34	......	1·34
	1872, 1873.													
30.	Dec. 30 to Jan. 4	1·79	0·71	......	2·50	0·75	3·25	,,	0·007	0·067	1·116	1·19	......	1·19
31.	Jan. 27 to Feb. 1	2·75	2·19	......	4·94	2·38	7·32	,,	0·126	0·05	0·86	1·04	......	1·04
32.	Mar. 3 to Mar. 8	1·45	0·68	......	2·13	1·21	3·34	,,	0·033	0·041	1·21	1·28	......	1·28
33.	Mar. 24 to Mar. 29	2·01	1·08	......	3·09	1·25	4·34	,,	0·033	0·123	1·00	1·16	......	1·16

TABLE III.—*Breton's Sewage-Farm.*

Statement showing the Monthly Quantities of Sewage distributed and Nitrogen contained therein, and of Effluent Water discharged and Nitrogen contained therein, for the period from March 25, 1872, to March 24, 1873.

Dates (inclusive).	Sewage or diluted sewage distributed.			Effluent water.				
	Quantity.	Nitrogen per 100,000 tons.	Total Nitrogen.	Quantity. Drains A, B, C, D.	Quantity. Drains E, F.	Quantity. Total.	Nitrogen per 100,000 tons.	Total Nitrogen.
1872.	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
March 25 to April 24	46,763	6·06	2·8338	16,802	8,111 (computed)	24,913	1·58	·3936
April 25 to May 24	46,695	4·62	2·1573	29,186	14,070 (computed)	43,256	·90	·3893
May 25 to June 24	43,850	4·02	1·7628	24,436	10,945 (computed)	35,381	·91	·3220
June 25 to July 24	38,263	3·96	1·5152	20,839	10,812 (computed)	31,651	1·00	·3165
July 25 to August 24	38,962	6·23	2·4273	20,384	9,891 (computed)	30,275	·95	·2876
August 25 to September 24	37,641	5·84	2·1982	23,675	11,066 (computed)	34,741	1·05	·3648
September 25 to October 24	32,578	5·10	1·6615	24,329	9,513 (partly computed)	33,842	1·33	·4501
October 25 to November 24	38,206	5·83	2·2274	32,201	18,590	50,791	1·27	·6450
November 25 to December 24	53,826	4·92	2·6482	35,801	15,553	51,354	1·26	·6471
1872. 1873.								
December 25 to January 24	56,361	5·28	2·9759	25,080	17,015	42,095	1·11	·4673
January 25 to February 24	45,673	6·33	2·8911	37,327	15,570	52,897	1·10	·5819
February 25 to March 24	48,775	3·84	1·8729	27,335	12,021	39,356	1·22	·4801
	527,593	5·151	27·1716	317,395	153,157	470,552	1·136	5·3453
Applied to Mr. Gooch's land and to garden	3,783							
Used at Breton's farm	523,810	5·151	26·9814					

The proportion of nitrogen escaping in the effluent water to the quantity applied is thereore ·1981, for about one fifth.

TABLE IV.—*Breton's*

Statement showing Sewage applied and Crops grown

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
A	1 to 20	6·41	Onions	April 1872...........	Sept. 1872 ....
"	21 and 29 (part)	1·79	Carrots	March "	Oct. " ....
"	21 to 28 (part)	1·59	Peas	June "	Sept. " ....
"	1 to 29	9·79	Cabbage	Oct. "	" " ....
Total A	....	9·79	....	....	.. ..
B	9 to 26	8·25	Cabbage................	Oct. 1871	May to Aug. 1872...
"	1 " 8	3·87	Italian rye-grass	Sept. 1870 and March 1871.	April to Aug. 1872.
"	21, 25, & 26	1·33	Hardy green plants...	April to June 1872..	Sept. 1872...........
"	9 to 16	3·72	Peas	June 1872	Aug. and Sept. 1872.
"	17 " 20	1·85	Hardy greens	Aug. and Sept. 1872.	Dec. 1872 and Jan. 1873.
"	1 " 7	3·39	Savoys	July and Aug. ..	Jan. to March 1873.
"	8 " 16	4·20	Cabbage..........	Sept. 1872	....
"	1 " 5	2·43	Oats	March 1873	....
"	6 " 7	·96	Wheat	"	.. ..
"	17 " 26	4·54	"	"	....
Total B	....	12·12	....	....	....
C	All	1·97	Oats	March 1872	Aug. 1872 ....
"	"	1·97	Hardy greens	Sept. "	Jan. and Feb. 1873.
"	"	1·97	Wheat	March 1873	....
Total C	....	1·97	....	....	....

The figures in columns marked thus (*) are to be considered

Sewage-Farm.

from March 25, 1872, to March 24, 1873.

Approximate estimate of sewage applied.			Produce.			
VII.	VIII.	IX.	X.	XI	XII.	Remarks.
No. of dressings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
17	10,650	1 661	65 9	10·3	162	9·75 tons of this crop ploughed in.
5	2,250	1,259	21·3	11·9	106	14·2 tons consumed by cattle on the farm
6	2,300	1,437	·4 0	2 3	575	Including straw, 3·5 tons consumed by cattle.
26	14,000	1,430	.	.	.. .	This crop remained March 25, 1873.
...	29,200	2,982	91·2	9·3	320	The whole plot was under crop at the end of the year.
31	23,550	2,855	153·6	18·6	153	This crop received 8577 tons of sewage previous to March 1872. 38·4 tons were consumed by cattle on the farm or ploughed in.
22	13,800	3,566	85·0	22·0	162	1108 tons sewage applied in March 1871.
6	1,500	1,128	12·8	9 6	117	One half of the plants were ploughed in.
6	6,050	1,626	10 0	2·7	605	Including straw, 8·4 tons consumed by cattle.
8	3 600	1,946	7·0	3 8	514	Ploughed in 1·4 ton.
10	7,700	2,271	29·6	8·7	260	5 9 tons ploughed in or consumed by cattle.
11	7,550	1 798	. ..	...	......	This crop remained March 25th, 1873.
”	......	...	.. ...	....	. ...	Crops remained March, 25th, 1873.
”	......	... .	.	...	......	
32	18,450	4,064	......	.. ..	. ...	
...	82,200	6,782	298·0	24 6	276	The whole plot was under crop at the end of the year.
...	......	......	6·8	3·4	......	4·6 tons straw. 20,328 tons of sewage applied to the fallow previous to sowing the oats.
30	8,850	4,492	6·7	3·4	1,321	3·3 tons ploughed in &c.
...	......	......	......	......	......	
...	8,850 *	4,492 *	13·5	6·8	656 *	Plot all under crop at the end of the year.

only as approximations, for reasons stated in the last Report.

TABLE IV.

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
D	All	6·93	Oats	March 1872	Aug. 1872............
"	"	6·93	Italian rye-grass	Aug. "	Nov. 1872 to March 1873.
Total D	....	6·93	....	.. ..	....
E	1 to 13	3·60	Italian rye-grass	March 1872	June to Sept. 1872...
"	14 " 22	2·17	Strawberries	.. ..	June to July " ...
"	2 " 13	3·30	Peas	June 1872	Sept. 1872 ....
"	1 " 22	5·76	Cabbage	Oct. "	.. ..
Total E	.. ..	5·76	.. . .	....	. ...
F	1 to 8	1·70	Carrots	April 1872............	Nov. 1872 ....
"	9 and 10	·42	Peas	June "	Sept. " ....
"	11 to 16	1·27	Potatoes	April "	" " ....
"	17 and 18	·42	Strawberries	March "	....
"	12 to 16	1·06	"	Sept. to Nov. 1872..	.. ..
Total F	....	3·82	....	....	....
G	13 and 14	·47	Hardy greens...........	Oct. 1871	May 1872 ....
"	1 " 2	·47	Mangold	April 1872...........	Nov. 1872 ....
"	3	·23	Carrots	May "	Dec. " ....
"	4 to 9	1·41	Onions	Aug. 1871	May to July 1872 ...
"	10 " 12	·70	Cabbage..	June 1872	Aug. 1872 ....
"	13 " 15	·70	Brussels sprouts	" "	Nov. 1872 to March 1873.
"	16	·23	Onions	May 1872	Nov. and Dec. 1872
"	17	·23	Potatoes.................	April "	Sept. 1872 ....
"	18 to 22	1·18	Onions	" "	Aug. " ....
"	4	·23	Kohl rabi	Aug. "	Dec. " ....
"	9	·23	Cauliflowers	July "	Aug. and Sept. 1872
"	{ 5 to 10 & 17 to 22 }	2·82	Cabbage..................	Sept. and Oct. 1872	....
Total G	....	5·17	....	....	....

The figures in columns marked thus (*) are to be considered

(*continued*).

Approximate estimate of sewage applied.			Produce.			Remarks.
VII.	VIII.	IX.	X.	XI.	XII.	
No. of dress-ings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
...	....	......	23·3	3·4	.. ...	16·2 tons straw.
27	17,750	2,561	34·7	5·0	511	The crop remained March 1873.
...	17,750	2,561	58·0	8·4	306	Plot all under crop at the end of the year.
6	3,850	1,069	9·1	2·5	423	Fallow received 6670 tons previous to sowing grass.
2	1,100	507	0·2	0·1	5500	
10	6,500	1,969	8·0	2·4	812	Straw 7·4 tons. Used on farm.
15	9,350	1,623	......	.....	......	Crop remained March 1873.
...	20,800	3,611	17·3	3·0	1202	Plot all under crop at end of year.
1	500	294	30·2	17.8	17	Tops used for fodder, 7·8 tons.
1	150	357	1·2	2·8	125	Straw used as fodder, ·94 ton.
...	......	.. ...	8·9	7·0		
1	200	476	.....	......	......	These plants remain. No yield at present.
...	......	......	.. ...	......	......	" " "
...	850	223	40·3	10·5	21	Beds 1 to 11 fallow all the winter.
...	......	......	2·3	4·9	......	Received 1109 tons of sewage previous to March 1872.
16	2,850	6,064	13·4	28·5	213	Tops &c. ploughed in 2 tons.
11	950	4,130	3·5	15·2	271	·66 ton tops used as fodder.
6	3,100	2,199	18·1	12·8	171	This crop received 802 tons of sewage previous to March 1872. 12 tons of the onions were ploughed in, there being no sale for them.
5	1,000	1,429	14·5	20·7	69	1·5 ton ploughed in.
4	950	1,357	5·8	8·3	164	3·1 tons ploughed in or consumed by cattle.
5	400	1,739	4·2	18·3	95	
2	150	652	1·3	5·6	115	
5	2,050	1,737	31·0	26·3	66	
5	400	1,739	1·5	6·5	267	
5	450	1,957	5·8	25·2	78	5·2 tons cut for cattle and ploughed in.
11	3,750	1,329	......	......	......	Crop remained March 1873.
...	16,050 *	3,104 *	101·4	19·6	158 *	Part of plot fallow all winter.

only as approximations, for reasons stated in the last Report.

TABLE IV.

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
H	1 to 24	6·40	Cabbage................	Sept. 1871	April to July 1872..
„	1 „ 17	4·25	Hardy greens	July 1872	Oct. to Dec. 1872 ..
„	18 „ 24	2·15	Cabbage................	June „	Aug. 1872 to March 1873.
„	1 „ 24	6·40	Onions	Feb. and March 1873	....
Total H	....	6·40	....	....	. ...
I	1 to 3 and 10 to 18	part 4·16	Cabbage and hardy greens.	Sept. and Oct 1872	April to July 1872
„	4 to 9	2·27	Potatoes............ ...	Feb. 1872	July 1872 ... .
„	1 „ 3	1·11	Cabbage...............	May „	Aug. 1872 to March 1873.
„	4 „ 9	2·27	Cabbage-plants	July „	Sept. and Oct. 1872
„	10 „ 15	2·32	Hardy greens	„ „	Oct. and Nov. „
„	16 „ 18	·97	Peas	June „	Sept. 1872 ....
„	4 „ 18	5·56	Fallow	....	.. . .
Total I	....	6·67	....	.. . .	....
K	All	4·44	Barley	April 1872	Aug. 1872............
„	„	4·44	Italian rye-grass.. ...	Sept. „	Nov. 1872, 1 cutting
Total K	....	4·44	....	....	....
L	All.	2·87	Fallow	... .	. .. .
„	Part.	·50	Mangold	June 1872.........	Nov. 1872. .. ..
„	„	2·37	Savoys	June and July 1872	„ „ to Jan. 1873.
„	All.	2·87	Fallow.....	....	.. ..
Total L	....	2·87	....	....	....
M	All.	3·17	Cabbage	Oct. 1871	June to Aug. 1872
„	„	3·17	Italian rye-grass	Sept. 1872	....
Total M	....	3·17	....	....	....

The figures in columns marked thus (*) are to be considered

(continued).

Approximate estimate of sewage applied.			Produce.			Remarks.
VII.	VIII.	IX.	X.	XI.	XII.	
No. of dressings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons	tons.	tons.	
32	19,950	3,117	101·1	15·8	197	10·6 tons ploughed in. The crop received 6387 tons of sewage previous to March 1872.
20	6,800	1,600	65·5	15·4	104	6·4 tons ploughed in.
14	7,750	3,605	45·3	21·1	171	4·7 tons consumed by cattle or ploughed in.
40	33,600	5,250	......	......	......	Crop remained March 1873. Sewage all applied to fallow.
...	68,100	10,641	211·9	33·1	321	Plot all under crop at end of year.
9	5,000	1 202	54·0	13·0	93	10·5 tons consumed by cattle or ploughed in.
2	1,250	551	7·3	3·2	171	
21	8,250	7,432	23·2	20·9	356	1·5 ton consumed by cattle or ploughed in.
2	650	286	25·8	11·4	25	
11	5,650	2,435	30·9	13 3	183	3 tons consumed by cattle or ploughed in.
7	1,450	1,495	2·6	2·7	558	Straw 2·3 tons.
24	19,250	3,462				
...	41,500	6,222	143·8	21·6	289	Nearly all this plot was fallow throughout the winter, and the whole clear at the end of the year.
.	......	. ..	15·3	3·4	.. .	10·4 tons straw.
19	10,750	2,421	6·7	1·5	1604	This grass remains.
...	10,750	2,421	22·0	4·9	489	Plot all under crop at end of year.
...	24,800	8,641				
4	1,300	2,600	4·1	8·2	317	1.25 consumed by cattle on farm.
11	3,830	1,616	49·7	21·0	77	Only one sixth of this crop sold; remainder destroyed by floods.
7	6,600	2,300				
...	36,530	12,728	53·8	18·7	679	
24	12,000	3,785	65·7	20·7	183	32·75 tons consumed by cattle or ploughed in. The crop received 4394 tons of sewage previous to March 1872.
10	4,950	1,561	......	.... .	......	Grass not cut till March 1873.
...	16,950 *	5,346 *	65·7	20·7	258 *	Standing crop at end of year.

only as approximations, for reasons stated in the last Report.

TABLE IV.

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive).	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
N	7 and 8	·52	Broccoli	July 1871	April 1872 ....
„	All.	4·15	Italian rye-grass	Mar. and May 1872	July „ to Jan. 1873.
Total N	....	4·15	....	....	....
O	All.	5·92	Wheat	Feb. 1872	Aug. 1872...........
„	„	5·92	Cabbage	Sept. „	„ „ ....
Total O	....	5·92	....	....	....
P	Part.	2·00	Hardy greens and savoys	April 1872	June 1872 to Mar. 1873.
„	„	1·50	Drumhead cabbage ...	May „	Oct. to Dec. 1872.
„	All.	3·50	Wheat	March 1873........	....
Total P	....	3·50	....	....	....
Q	1 to 10	1·04	Barley	May 1872	Sept. 1872...........
„	11 to 20	1·07	Savoys	July „	Nov. „ to Jan. 1873.
„	21 and 22	·23	Drumhead cabbage ...	May „	Nov. 1873..........
„	1 to 10	1·04	Cabbage	Oct. 1873	....
„	11 to 22	1·30	Fallow	....	....
Total Q	....	2·34	....	....	....
R	All.	2·52	Mangold	April 1872	Nov. 1872...........
„	Part.	2·40	Fallow	....	....
„	„	·12	Oziers	Jan. 1873	....
Total R	....	2·52	....	....	....
S	All.	·22	Onions	March 1872	July and Aug. 1873.
„	„	·22	Hardy greens	Aug. „	Dec. 1872 ....
„	„	·22	Rhubarb	Feb. „	....
Total S	....	·22	....	....	....

The figures in columns marked thus (*) are to be considered

(*continued*).

Approximate estimate of sewage applied.			Produce.			
VII.	VIII.	IX.	X.	XI.	XII.	Remarks.
No. of dress-ings.	Total. *	Per acre. *	Total.	Per acre.	Sewage applied per ton of produce. *	
	tons.	tons.	tons.	tons.	tons.	
...	......	......	13·8	26·5	......	This crop received 2194 tons of sewage previous to March 1872. 11 tons consumed by cattle or ploughed in.
75	37,950	9,145	187·9	45·3	202	Grass cut 6 times and still remains.
...	37,950	9,154	201·7	48·6	188	Standing crop at end of year.
...	......	......	20·7	3·5	......	30 qrs. wheat = 6·75 tons, tail wheat = ·45 tons, straw 13·5 tons.
31	21,100	3,564	......	......	......	This crop remained March 1873.
...	21,100	3,564	20·7	3·5	1019	Standing crop at end of year.
52	16,300	8,150	22·7	11·3	718	10 tons consumed by cattle or ploughed in.
55	18,450	12,300	45·1	30·1	409	30 tons consumed by cattle or ploughed in.
...	......	......	......	......	......	The crop remained March 1873.
...	34,750	9,927	67·8	19·4	513	Standing crop at end of year.
...	......	....	2·6	2·5	......	2·12 tons straw.
3	1,150	1,075	23·6	22·1	487	15·7 tons consumed by cattle or ploughed in.
1	150	652	3·2	13·9	47	2·1 tons consumed by cattle or ploughed in.
2	250	240	......	......	......	Crop remained March 1873.
2	550	423				
...	2,100	897	29·4	12·6	71	
3	1,450	575	46·6	18·5	31	5 tons small mangolds ploughed in.
14	8,150	3,396				
13	680	5,667	......	......	......	Crop remained March 1873.
...	10,280	4,079	46·6	18·5	221	
2	400	1,818	1·8	8·2	222	
2	150	682	2·1	9·5	71	·33 ton consumed by cattle or ploughed in.
...	......	......	......	......	......	Crop remained March 1873.
...	550 *	2,500 *	3·9	17·7	141 *	Standing crop at end of year.

only as approximations, for reasons stated in the last Report.

TABLE IV.

Description.					
I.	II.	III.	IV.	V.	VI.
Plot.	No. of beds (inclusive)	Contents.	Crop.	Date when sown or planted.	Date when cut or gathered.
		acres.			
U	All.	2·53	Sprouting broccoli ...	Oct. 1871	April 1872 ....
„	„	2·53	Dwarf and runner beans.	May 1872	Aug. „ ....
„	„	2·53	Wheat	March 1873	....
Total U	....	2·53	....	....	....
V	Part.	·50	White broccoli........	June 1871	April 1872 ....
„	„	2·00	Cabbage	Oct. „	May to Aug. 1872
„	„	2·88	Barley	May 1872	Sept 1872 ....
„	„	2·00	Hardy greens	Sept. „	March 1873 ....
„	„	2·93	Cabbage	Oct. „	.. ..
Total V	....	4·93	....	....	....
W	All.	3·0	Oats	March 1872	Aug. 1872............
„	Part.	2·75	Hardy greens	Sept. „	Feb. and Mar. 1873
„	„	2·75	Wheat	March 1873	....
Total W	....	average 2·87	....	....	....
X	All.	3·86	Fallow	....	....
„	Part.	3·36	Mangold	May 1872	Nov. 1872............
„	„	·50	Savoys	July „	Nov. „ to Mar. 1873.
„	All.	3·86	Wheat	March 1873	....
Total X	....	3·86	....	....	....
Y	All.	5·60	Hay	Permanent grass ...	2 cuttings, June and Sept. 1872.

The figures in columns marked thus (*) are to be considered

(*continued.*)

Approximate estimate of sewage applied.			Produce.			Remarks.
VII.	VIII.	IX.	X.	XI.	XII.	
No. of dressings.	Total. *	Per acre. *	Total.	Per acre	Sewage applied per ton of produce. *	
		tons.	tons.	tons	tons.	
...	......	.....	13·4	5·3	.....	This crop received 5797 tons of sewage previous to March 1872. The greater portion of crop consumed by cattle or ploughed in.
15	7,900	3,122	7·2	2·8	1097	Three fourths of this crop was ploughed in.
37	9,550	3,775	.....	......	.....	Crop remains; sewage all applied to the fallow.
...	17,450	6,897	20·6	8·1	847	Standing crop at end of year.
...	.....	......	14·5	29·0	......	Four fifths of this crop ploughed in or consumed by cattle. Received 2126 tons of sewage previous to March 1872
3	2,950	1,475	35·1	17·5	84	Consumed by cattle and ploughed in 4 tons. Received 2053 tons of sewage previous to March 1872.
...	......	..	7·2	2·5	...	Straw, 5·8 tons.
7	2,800	1,400	4·7	2·3	596	Consumed by cattle or ploughed in 2·5 tons.
5	3,000	1,024	......	...	...	Crop remained March 1873.
...	8,750	1,775	61·5	12·5	142	Standing crop on part of plot at end of year.
...	......	......	10·2	3·4	......	Fallow received 8345 tons sewage previous to March 1872. Straw 6·9 tons.
33	9,600	3,491	6·0	2·2	1600	Consumed by cattle or ploughed in 3 tons.
...	......	.. ...	......	......	......	Crop remained March 1873.
...	9,600	3,345	16·2	5·6	593	Plot in seed at end of year; quarter acre of plot taken for gravel-pit, &c.
7	5,000	1,295				
7	6,150	1,830	84·0	25·0	73	Waste 8·4 tons.
4	650	1,300	10·1	20·2	64	Five sixths of this crop injured by floods and consumed by pigs or ploughed in.
14	14,800	3,834	......	.. ...	......	All this sewage applied to the fallow. Crop remained March 1873.
...	26,600	6,891	94·1	24·4	283	Plot in seed at end of year.
7	5,150 *	920 *	24·6	4·4	209 *	The grass remains; 2400 tons of this sewage applied since the second cutting.

only as approximations, for reasons stated in the last Report

TABLE V.—*Breton's*

Summary for the year ending March 24, 1873, showing the Nitrogen applied

Description.			Produce.		Approximate estimate of sewage applied.		
Plot.	Contents.	Crop.	Total.	Per acre.	Total. *	Per acre. *	Per ton of produce. *
	acres.		tons.	tons.	tons.	tons.	tons.
A	9·79	Onions, carrots, and peas	91·2	9·3	29,200	2,982	320
B	12·12	Cabbage, Italian rye-grass, hardy green plants, peas, and savoys	298·0	24·6	82,200	6,782	276
C	1·97	Oats and hardy greens	13·5	6·8	8,850	4,492	656
D	6·93	Oats and Italian rye-grass	58·0	8·4	17,750	2,561	306
E	5·76	Italian rye-grass, strawberries, and peas	17·3	3·0	20,800	3,611	1202
F	3·82	Carrots, peas, and potatoes	40·3	10·5	850	223	21
G	5·17	Hardy greens, mangold, carrots, onions, cabbage, Brussels sprouts, potatoes, kohl rabi, and cauliflowers.	101·4	19·6	16,050	3,104	158
H	6·40	Cabbage and hardy greens	211·9	33·1	68,100	10,641	321
I	6·67	Cabbage, hardy greens, potatoes, and peas	143·8	21·6	41,500	6,222	289
K	4·44	Barley and Italian rye-grass	22·0	4·9	10,750	2,421	489
L	2·87	Mangold and savoys	53·8	18·7	36,530	12,728	679
M	3·17	Cabbage	65·7	20·7	16,950	5,346	258
N	4·15	Broccoli and Italian rye-grass	201·7	48·6	37,950	9,145	188
O	5·92	Wheat	20·7	3·5	21,100	3,564	1019
P	3·50	Hardy greens, savoys, and cabbage	67·8	19·4	34,750	9,927	513
Q	2·34	Barley, savoys, and cabbage	29·4	12·6	2,100	897	71
R	2·52	Mangold	46·6	18·5	10,280	4,079	221
S	·22	Onions and hardy greens	3·9	17·7	550	2,500	141
U	2·53	Dwarf and runner beans and sprouting broccoli	20·6	8·1	17,450	6,897	847
V	4·93	White broccoli, cabbage, hardy greens, and barley	61·5	12·5	8,750	1,775	142
W	2·87	Oats and hardy greens	16·2	5·6	9,600	3,345	593
X	3·86	Mangold and savoys	94·1	24·4	26,600	6,891	283
Y	5·60	Hay (equal to four and a half times this quantity when green)	24·6	4·4	5,150	920	209
	107·55		1704·0	15·85	523,810	4,870	307

The figures in columns marked thus (*) are to be considered only as approximations

Sewage Farm.

to the Land during that period, and its relation to the Produce of the Farm.

Approximate estimate of nitrogen.															
Quantity applied.			Quantity escaping in effluent water.	Difference (in soil, crops, &c.)			Calculated to be in crops.			Not accounted for (in standing crops, soil, and drained away).			Per cent.		
Total. *	Per acre. *	Per ton of produce. *	*	Total. *	Per acre. *	Per ton of produce. *	Total.	Per acre.	Per ton of produce.	Total. *	Per acre. *	Per ton of produce. *	In crop. *	In effluent water. *	Not accounted for (in soil). *
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.			
3,369	344	36·9	668	2,701	276	29·6	725	74	7·9	1,976	202	21·7	22	20	58
9,485	783	31·8	1,879	7,606	627	25·5	2,927	242	9·8	4,679	386	15·7	31	20	49
1,021	518	75·6	202	819	416	60·7	198	101	14·7	621	315	46·0	19	20	61
2,048	295	35·3	406	1,642	237	28·3	954	138	16·4	688	99	11·9	46	20	34
2,400	416	138·7	476	1,924	334	11·2	719	125	41·5	1,205	209	69·7	30	20	50
98	26	2·4	19	79	21	1·9	276	72	6·8	......	......	......	282	20	
1,852	358	18·3	367	1,485	287	14·6	533	103	5·3	952	184	9·4	29	20	51
7,858	1228	37·1	1,557	6,301	985	29·7	1,187	185	5·6	5,114	800	24·1	15	20	65
4,789	718	33·3	949	3,840	576	26·7	989	148	6·9	2,851	427	19·8	21	20	59
1,240	279	56·4	246	994	224	45·2	373	84	17·0	621	140	28·0	30	20	50
4,215	1473	78·3	835	3,380	117	62·8	301	105	5·6	3,079	1073	57·2	7	20	73
1,956	617	29·8	387	1,569	495	23·9	368	116	5·6	1,201	383	18·3	19	20	61
4,379	1055	21·7	867	3,512	846	17·4	2,350	566	11·7	1,162	280	5·7	54	20	26
2,435	411	117·6	482	1,953	330	94·3	472	80	22·8	1,481	250	71·5	19	20	51
4,010	1146	59·1	794	3,216	919	47·4	380	109	5·6	2,836	810	41·8	9	20	71
242	103	8·2	48	194	83	6·6	191	82	6·5	3	1	·1	79	20	1
1,186	471	25·5	235	951	377	20·4	261	104	5·6	690	273	14·8	21	20	59
63	286	16·2	12	51	232	13·1	21	95	5·4	30	137	7·7	33	20	47
2,013	796	97·7	399	1,614	638	78·3	156	62	7·6	1,458	576	70·7	8	20	72
1,009	205	16·4	200	809	164	13·2	419	85	6·8	390	79	6·4	41	20	39
1,107	386	68·3	219	888	310	54·8	275	96	17·0	613	214	37·8	20	20	60
3,06	795	32·6	608	2,461	638	26·2	527	137	5·6	1,934	501	20·6	19	20	61
594	106	24·1	118	476	85	19·3	1,102	197	44·8	......	......	......	186	20	
60,438	**562**	**35·5**	**11,973**	**48,465**	**451**	**28·5**	**15704**	**146**	**9·2**	**32,761**	**350**	**19·2**	**26**	**20**	**54**

(for reasons stated in the last Report), with the exception of the grand totals.

TABLE VI.—*Breton's*

Summary from Crops gathered during the period from March 25, 1872, to
Sewage applied

[N.B.—The Sewage here stated is only that applied during the above period. In

Crop.	Total acreage of each description of crop.	Produce of each crop.		Sewage ap- the
		Total.	Per acre.	Total. *
	acres.	tons.	tons.	tons.
Italian rye-grass	22·99	323·4	14·1	84,100
Hay (meadow)	5·60	24·6	4·4	5,150
Cabbage	27·78	512·6	18·5	94,700
Hardy greens	17·16	138·0	8·0	38,950
Savoys	7·33	113·0	15·4	13,330
Brussels sprouts	·70	5·8	8·3	950
Broccoli	3·55	41·7	11·7	....
Cauliflowers	·23	5·8	25·2	450
Kohl rabi	·23	1·5	6·5	400
Beans (dwarf and runner)	2·53	7·2	2·8	7,900
Peas	10·00	25·8	2·6	16,450
Carrots	3·72	55·0	14·8	3,700
Mangold	6·85	148·1	21·6	11,750
Onions	9·45	121·0	12·8	16,600
Potatoes	3·77	17·5	4·6	1,400
Oats	11·90	grain 12·6 straw 27·7	1·1 2·3	....
Barley	8·36	grain 6·8 straw 18·3	0·8 2·2	....
Wheat	5·92	grain 7·2 straw 13·5	1·2 2·3	....
Strawberries	2·17	0·2	0·1	1,100
Mixed crops—cabbage and hardy greens and savoys	6·16	76·7	12·4	21,300
To fallow land and to land under crop March 25, 1873	85·25	....	......	205,580
Total	241·65	1704·0	......	523,810

The figures in columns marked thus (*) are to be considered as approximations

Sewage-Farm.

March 24, 1873, showing the quantity of each kind of Produce and the thereto.

some cases, therefore, it does not represent the total quantity applied to the Crops.]

plied to crops.	Sewage applied per ton of produce. *	Nitrogen.				
Per acre. *		Quantity applied in sewage. *	Quantity escaping in effluent water. *	Quantity estimated in crops. Per acre.	Quantity estimated in crops. Total.	Not accounted for (in standing crops, soil, &c.). *
tons.	tons.	lbs.	lbs.		lbs.	lbs.
3658	26	9,702	1,923	0·54	3,912	3,867
920	209	594	118	2·00	1,102	....
341	185	10,924	2,164	0·25	2,871	5,889
2269	282	4,493	890	0·25	773	2,830
1819	118	1,538	305	0·25	633	600
1357	164	110	22	0·25	32	56
......	......	....	....	0·25	234	....
1957	78	52	10	0·25	32	10
1739	267	46	9	0·375	13	24
3123	1097	911	181	0·50	81	649
1645	638	1,898	376	3·40	1,965	....
995	67	426	84	0·20	246	96
1715	79	1,356	269	0·25	829	258
1756	137	1,915	379	0·22	596	940
371	80	162	32	0·25	98	32
......	......	....	....	grain 2·0, straw 0·6	937	....
......	......	....	....	grain 1·6, straw 0·5	448	....
......	......	....	....	grain 1·8, straw 0·6	472	....
507	5500	127	25	0·1	....	102
3458	278	2,456	486	0·25	430	1,540
2412	......	23,728	4,700	....	....	19,028
......	307	60,438	11,973	....	15,704	32,761
	per cent. ...100		20	....	26	54

(for reasons stated in the last Report), with the exception of the grand totals.

TABLE VII.—*Breton's Sewage-Farm.*

Comparative Statement of Crops on Land and Land lying fallow on March 24, 1872, and March 24, 1873 respectively.

Plot.	March 24, 1872.			March 24, 1873.		
	Acreage.	Area in crop.	Area fallow.	Acreage.	Area in crop.	Area fallow.
	acres.	acres.	acres.	acres.	acres.	acres.
A	9·8	......	9·8	9·79	9·79	......
B	12·1	12·1	......	12·12	12·12	......
C	2·0	......	2·0	1·97	1·97	......
D	6·9	......	6·9	6·93	6·93	......
E	5·8	2·2	3·6	5·76	5·66	......
F	3·82	......	3·82	3·82	1·48	2·34
G	5·17	1·88	3·29	5·17	2·82	2·35
H	6·4	6·4	......	6·4	6·5	......
I	6·67	3·40	3·27	6·67	......	6·67
K	4·03	......	4·03	4·44	4·44	......
L	......	.....	......	New plot. 2·87	......	2·87
M	3·36	3·36	......	3·17	3·17	......
N	4·15	0·52	3·63	4·15	4·15	......
O	5·92	......	5·92	5·92	5·92	......
P	3·50	......	3·50	3·50	3·50	......
Q	1·60	......	1·60	2·34	1·04	1·0
R	2·52	......	2·52	2·52	·12	2·40
S	0·33	......	0·33	0·22	·22	.....
T	0·34	......	0·34	Plot converted into a pig-run.		
U	2·53	2·53	......	2·53	2·53	......
V	4·48	2·50	1·98	4·93	2·93	2·00
W	3·00	......	3·00	2·87	2·87	......
X	3·86	......	3·86	3·86	3·86	......
Y	5·60	5·60	.....	5·60	5·60	......
	103·88	40·49	63·39	107·55	87·62	19·93

TABLE VIII.

A Statement showing the population in the Town Ward of Romford, with and without connexion with the main sewer running to Breton's Farm.

Detail.	Houses.		Water closets.		Other closets.		Slops.		Number of inhabitants.	Water-supply.		Remarks.
	Occupied.	Empty.	Connected.	Not connected.	Connected.	Not connected.	Connected.	Not connected.		Water company.	Private.	
Fully connected	951	59	233	...	786	...	850	..	4438	328	683	
Partly connected.................	15	...	9	...	10	15	15	...	112	7	8	All connected except the 15 closets.
Slops only connected	40	...	...	23	...	58	26	...	747	5	35	Including the Union 328 inhabitants.
Withont any connexion.........	182	12	...	9	...	205	...	191	890	44	149	
Without any connexion, that stand on the outskirts of the Town Ward	30	1	...	7	...	36	...	31	151	...	31	Being Marshallo Park, Pethls Lane, and Rush Green.
General Total	1218	72	242	39	796	314	891	222	6338	384	906	

(Signed) HY. CULLEM, May 4, 1873.

An Abstract of the Four Reports already presented to the Association by the Committee. Prepared for the Committee by Professor CORFIELD.

In the following Abstract of the four Reports already presented to the Association by the Committee, I have thought it best to bring together the results of the Committee's investigations under a few heads; so that each division of the subject may appear in the Abstract complete in itself, and not split up into portions, as would have been the case had each Report been abstracted separately.

I. *Conservancy Plans.*

A series of Reports "from foreign countries respecting the practices prevailing abroad for disposing of the refuse of towns, villages, public institutions, factories, dwellings, &c., and having reference to the sanitary condition of the districts in which they are situated, the state of rivers, or the support and increase of the produce of the soil," was obtained by the Committee from Her Majesty's Secretary of State for the Home Department; and from these it appeared "that in most cases (both in town and country places) the use of privies is very general, water-closets being rare even in large towns, and that the usual method of dealing with human excreta is to allow them to collect in pits (Abtrittsgruben, fosses), which are sometimes drained either naturally by the permeable character of the soil, or artificially, so that most or all of the liquid portion of the contents of the pits flows away or infiltrates the surrounding soil." (Report I. 1869, pp. 318–321.)

Information was also obtained from 107 places in the United Kingdom, having an aggregate population of more than four millions. It was found that in 42 of these the privy and ash-pit system was general, and in 25 partial; while in 71 places out of the 107 the liquid refuse of the town was discharged into the adjoining stream or river, and in two instances into pools of water. (Report I. p. 325.)

In the Second Report the returns from 200 towns, "recording the existing arrangements of water-supply, sewerage, scavengering, and disposal of refuse," are tabulated—the result being that there were 70 of these towns where "privies very greatly exceed water-closets in number," and 75 in which "privies are still much used." (Report II. 1870, p. 53.)

Privies, both in England and abroad, were found to be frequently built over rivers (Report I. pp. 318–321, and Report II. p. 59); and in some towns many houses are without any provision whatever for the removal of the excremental matters.

It was found that in only two instances in England, and one in Scotland, was any profit derived "from the sale of ashes and excretal and other solid refuse," the losses of some towns being considerable (Report II. p. 55). The Committee specially investigated the ash-pit system as carried out at the town of Bury in Lancashire, for two reasons—"because it is a town where it may be said there are no water-closets," and because "the almost total absence of water-closets" would enable the Committee, by examining the liquid escape into, and discharge from, the sewers, to judge whether any of the proposed methods of intercepting fæcal matter from the sewers (such, for instance, as the earth-closet) would in themselves be either a solution of the great sewage question, or even one considerable step towards it.

It was found that the privy accommodation of the lower classes of houses was very insufficient—that the removal of the mixed night-soil was found to be difficult and expensive, so that the quantity obtained from the whole town only realized £100 per annum—and that, in spite of the fact that so

much refuse matter was kept out of the sewers, the sewage during the greater part of the day was, as shown by chemical analysis, only a little weaker than that of a water-closeted town usually is, while during the forenoon it was invariably "very thick, black, and greasy," and "smelt very bad;" and the Subcommittee appointed to consider the matter reported, "that although the sewage from a town managed on the Bury system is weaker, and therefore less valuable, and proportionately more difficult to deal with than the sewage from a water-closeted town, yet that its purification is just as imperatively necessary." The Subcommittee considered that "the figures obtained in Bury, of the ash-pit system as carried out there, prove that financially it is, so far as Bury is concerned, a total and complete failure, as the gross return is only a little over one halfpenny per head of the population annually."

In many towns, especially abroad, portable or fixed reservoirs (fosses) for the collection of excretal matters, unmixed with other substances, are in general use. Sometimes they are drained into sewers, and sometimes so constructed as to collect both liquid and solid refuse, contrivances to separate the solid from the liquid excreta being sometimes employed. These reservoirs are "frequently ventilated by means of shafts rising above the house-tops." The fixed reservoirs are emptied periodically, their contents either being "simply dipped out," or "removed either by pumping into closed tank-carts with lift-pumps, or by means of a vacuum previously produced in the tank-cart." The portable reservoirs are removed bodily with their contents, and replaced by empty ones. At some towns a profit is realized, while at others a loss is entailed; but the communications received from foreign countries afforded "abundant evidence that, wherever the subject has been considered, there is a strong though vague sense of the injury to health resulting from the accumulation of excretal materials in pits &c. within populous districts, by the impregnation of the soil, by the pollution of rivers and well-water with drainage from such accumulations, or from the discharge of excretal materials into watercourses directly or indirectly." (Report I. pp. 321 & 322.)

Dry Earth System.

In the 200 scheduled towns before referred to, only 446 earth-closets were reported to exist. The Committee inquired into the results of this system at several places, but only obtained a return from Lancaster, "the only place where an attempt has been made to carry out the system on a large scale," where it appeared that the system was not thoroughly carried out, some of the essential conditions to its success being entirely neglected. Thus, instead of the dried earth being used *in detail*, "a quantity of soil is thrown once a day on the matters collected; and the result is that the product is removed in a very offensive condition." When it is stated that about 2½ lbs. of soil were used per head per day, and that the manure was afterwards mixed with other town refuse, it is not surprising that it only fetched 5*s*. a ton, and that its analysis showed "that it did not contain more nitrogen than good garden-mould," and that, on being applied to grass land at the rate of about six tons per acre, "the produce of hay was by no means large."

Dr. Gilbert conducted, on behalf of the Committee, some experiments with Moule's earth system. The result showed that earth which had been used even *three times* in the closet could only be considered to be a rich garden-mould; and the Committee remarked "that such a manure, even if disposed of free of charge, would bear carriage to a very short distance only."

The following Table shows the results of these analyses, as far as the nitrogen is concerned :—

	Before used.	After using once.	After using twice.	After using three times.
Percentage of nitrogen in soil dried at 100° C.	0·073	0·240	0·383	0 446

While the Committee considered that any such system was impracticable for large populations, on account of the amount of earth that would be required to be carted in and out daily, they added, "It may readily be admitted that it would be a great advantage, in a sanitary point of view, in the cases of sick rooms, detached houses, or even villages, and that it might be even economical where the earth for preparation and absorption and the land for utilization are in close proximity." (Report III. pp. 187 & 188, and Report IV. p. 143.)

II. *Water-Carriage System.*

This is only carried out in a few foreign towns (Report I. pp. 321–323). Of the 107 places reported on by the Committee in their First Report, there were only 11 without any system of sewerage at all; 48 were completely sewered, and 48 partially so. In 42 places water-closets were found to be general, and in 25 adopted partially. In the 200 towns scheduled in the Second Report, there were 44 in which water-closets were found to be general, and 75 in which they existed in considerable number; but there were only 11 of these 200 towns also which were totally unprovided with sewers, and in which the liquid refuse of various sorts found its way into surface-streams or was absorbed by the subsoil—a sufficient proof that Conservancy plans do not get rid of the necessity of having sewerage arrangements in towns.

As to water-supply, the sources appear to be exceedingly various. "In the 200 scheduled towns there are 90 wholly dependent on a public or general supply, 22 on private sources only, and 88 partly on private sources in addition to a public supply." The quantity supplied varied from 10 to 60 gallons per head per day, a large number of towns having a supply varying from 20 to 30 gallons per head. Storm and surface-waters are, as a rule, received into the sewers; but sometimes, "where new systems of sewerage have been adopted, the old sewers are entirely devoted to the discharge of surface-waters; in one instance special sewers are appropriated to the same purpose, while in 11 other instances the old surface-channels are used."

It was found that in about 100 out of the 200 towns the sewers drained the subsoil. The 200 towns were arranged in three classes as follows :—

	Towns.	Population.
I. Towns having a complete system of underground sewerage, a general water-supply, and a general adoption of water-closets discharging into the sewers	44	1,154,600
*II. Towns having a system of underground sewerage with water-supply, and only a partial adoption of water-closets	145	5,785,840
III. Towns with no system of underground sewerage	11	218,800
Total	200	7,159,240

* In this class there are some towns with as few as six water-closets only.

Only vague information was obtained about the ventilation of the sewers, "owing to the fact that very few instances exist in which any thing has been systematically done." The Committee in their First Report stated that this was a most important matter for consideration, and "that it would be in the highest degree desirable to institute an inquiry into the nature of the gaseous emanations from the sewers in various places" (Report I. p. 330). They consequently instituted some experiments, both chemical and microscopical, on air collected from some sewers in Paddington. Dr. Russell's analyses showed that the carbonic acid varied from 0·12 to 0·51 per cent., and the oxygen from 20·7 to 20·91 per cent.; while no combustible gases were detected, and only a trace of ammonia could be discovered in water through which a large quantity of sewer air had been passed. The remark is made that "these experiments must be looked upon as simply tentative, but certainly indicate a purer air in these sewers than might have been anticipated." The microscopical examination conducted by Mr. Cooke showed that the suspended substances which were collected by passing air through tubes containing plugs of cotton-wool were very various, and consisted of inorganic matters, a few starch-granules, and spores of various sizes, together with fragments of cellular tissue, woody fibre, fibrils of feathers, &c. The general results, however, indicated "comparative freedom from organic bodies." (Report II. pp. 72–75.)

The Committee made a special investigation into the sewerage arrangements of the town of Cambridge, where water-closets are general, though not universal. The outlets of all the sewers were found to be under the level of the surface-water in the Cam, so that "the sewage is backed up in the sewers for a considerable distance; and the subsoil is constantly saturated with both water and sewage in the lowest parts of the town." As many of the sewers are old and of irregular shape, much escape into the subsoil takes place. "Inquiries were made into the state of some of the wells belonging to private houses, and it was found that they were all contaminated by sewage, owing to their proximity to the sewers in the streets and to the drains on the premises, so much so, that the water cannot be used for drinking but only for washing." The remarks made on the subject by the Subcommittee, consisting of Messrs. Grantham (Chairman), Corfield, Hope, and Williamson, finish as follows:—

"The chief general importance of the inquiry into the conditions of Cambridge is the proof thus obtained of the pollution of wells, and therefore of subsoil, by the agency of previous street- or house-sewers constructed in their vicinity; and the Subcommittee desires to give expression to the conviction forced upon it in the course of its inquiries, that all sewers, properly so called (that is to say, drains into which refuse from human habitations is admitted), ought to be constructed of materials which are altogether impervious, and that a separate system of pervious drains, similar to agricultural drains, should be constructed where necessary to dry the subsoil. The Subcommittee is of opinion that the further construction of pervious sewers should be prohibited by Parliamentary enactment." (Report II. p. 61.)

The amount of sewage discharged varied in the 200 towns scheduled, partly with the amount of the water-supply, and partly with the amount of surface or subsoil waters admitted into the sewers—the largest quantity being in the case of the town of Hertford, where the discharge per head per diem amounted to 257 gallons, the water-supply being only 61½ gallons; and the smallest, amounting to only six gallons per head per diem, being recorded in one or two instances.

Treatment of Sewage.

"Of the 189 towns and districts having systems of sewerage, 143 discharge their sewage without any treatment whatever; in 17 instances the sewage is simply filtered before discharge, in 7 instances it is chemically treated, and in 17 cases recourse is had to irrigation, whilst in 5 instances the system of disposal includes more than one of these methods." By "simple filtration" is generally meant mere straining, a method obviously insufficient for the purification of sewage.

Certain processes for precipitating the valuable materials contained in sewage were investigated by the Committee with the following results:—

I. *The Phosphate Process* of Messrs. Forbes and Price, which consists in the addition to the sewage of (*a*) a mixture of native phosphate of alumina and sulphuric acid, and (*b*) sufficient milk of lime to neutralize the sewage. The result was that during its passage through a large tank "the suspended matters were very completely deposited, and the supernatant water ran over the sloping edge of the tank at its extreme end bright and clear and almost odourless." It was found that the water did not putrefy, even after the lapse of four months, that it contained only the merest trace of phosphoric acid, no sulphuretted hydrogen, nor any nitrates nor nitrites, but that it contained "as much actual ammonia as ordinary dilute London sewage, and also a certain "amount of albumenoid ammonia." The precipitate had no offensive smell. The valuable constituents of sewage, with the exception of the suspended matters and the phosphoric acid, are not precipitated by this process, and cannot be utilized unless the effluent water be afterwards used for irrigation, in which case the milk of lime would not be added, and the clarified sewage would still contain a quantity of phosphoric acid.

"The advantage of this use of it, if it were found to answer from an economical point of view, would be the deodorization of the deposit in the tanks and of the sewage itself, which is certainly at present a great desideratum, especially as regards the tanks." (Report III. pp. 185-187.)

II. *Whitthread's Patent.*—Experiment was made on 100 gallons of Romford sewage with one pound of the mixture used in this process—a mixture which was stated to consist of dicalcic and monocalcic phosphate, two equivalents of the former to one of the latter, a little milk of lime being afterwards added. The result was a very rapid precipitation, the supernatant water remaining nearly clear and quite inoffensive. The precipitate, dried at 100° C., contained as much as 3 per cent. of ammonia and a considerable quantity of phosphate of lime. The supernatant water contained rather more actual ammonia than the original sewage, but scarcely any organic nitrogen, showing that the organic matters in solution, as well as those in suspension, had been almost entirely removed by the process. This water contained, however, a considerable quantity of phosphoric acid, which would be valuable if the water were afterwards used to irrigate land; "but, unless means are devised for separating it, it would constitute a serious loss if the water were thrown away." It must be added that this was regarded merely as a preliminary experiment.

III. *General Scott's Process.*—This was investigated at Ealing. It consists in the addition to the sewage, while in the sewers, of a mixture of lime and clay, in the proportion of about 10 cwt. of the former and 5 cwt. of the latter to 400,000 gallons of sewage. The result was a very complete precipitation of the suspended matters, which were collected in tanks, the supernatant water being passed upwards through filter-beds, and discharged

into the river. The sludge from the tanks is drawn off from time to time, partially dried by an hydraulic press, and then burnt in a kiln, no additional fuel being necessary after the fire is once started, as the dried sludge contains sufficient organic matter to burn the deposit. The result is the production of cement. It was found that the sewage was rendered inodorous while in the sewers, and that the whole process was inoffensive.

The Committee considered that "on the whole this process, when perfected, promises well as a means of treating one of the difficulties of the sewage question—the disposal of the sludge precipitated from sewage. It appears not only possible to destroy the solid matters by fire, but also to secure some return from their use in the manufacture of cement."

They found, however, that the effluent water contained organic matters in solution as well as ammonia; so that this process cannot be considered as sufficient of itself for the purification of sewage, nor for its utilization, but only as one for satisfactorily getting rid of the offensive sludge which otherwise accumulates in the tanks.

Filtration.

Upward Filtration.—The process of upward filtration through gravel was examined at Ealing when General Scott's process was in abeyance. It was found that this process, whether accompanied or not by the addition of a deodorizing mixture to the sewage in the sewers in the town, "effected only a very slight purification of the sewage, which left the filter still a sewage of average strength. It was not even clarified." This observation thus confirmed the results of experiments previously carried out by the Rivers' Pollution Commissioners.

Weare's Process.—This process, which is employed at the Workhouse at Stoke-upon-Trent, where the water-supply is very scanty and the sewage consequently remarkably strong, consists in the filtration of the sewage through coarse ashes and charcoal contained in the tanks through which it passes successively. It appeared to be considerably purified; but still the effluent water after passing through the deodorizing tanks is described by Dr. Russell as having a strong smell of sewage. It is also to be observed that no nitrates were found in this water, thus showing that no oxidation had taken place. From the fact that the flow of effluent water was only about 2000 gallons as against 5000 gallons of sewage in the 24 hours, and that the chlorine was reduced to nearly half its original amount, the reduction taking place almost entirely in the first or so-called fæcal tank, it would appear that a considerable dilution must in some way have taken place, accompanied by a very considerable and unexplained escape, which amounted, even supposing there were no dilution, to three fifths of the total amount.

Intermittent downward Filtration.

This process was examined at Troedyrhyw, near Merthyr Tidfyl, where an area of about 20 acres has been converted into a filter-bed for the purification of the sewage of the town of Merthyr Tidfyl. The soil consists chiefly of gravel and sand, having a vegetable-mould on the surface. It is extremely porous. The land is drained at a depth of less than 7 feet, the drains being brought together at the lowest corner, where the effluent water is discharged into an open drain leading to the river Taff. "The area is laid out in square beds, intersected with roads and paths, along which are constructed the main carriers which receive the sewage from the outfall-sewer, and distribute it over the beds."

The sewage, after being screened through a bed of "slag," in which the larger suspended matters are arrested, is turned on to one of the four plots into which the area is divided, and allowed to run on this plot for six hours, when it is turned on to another one. Thus each of these four plots has 18 hours for rest and aëration of the soil. The surface of the area is laid up in ridges, and cabbages and other vegetables planted along them, the sewage running in furrows between.

The main results of the examinations which took place in January and in July, extending over seven and eight days respectively, were:—that the effluent water discharged was very largely diluted with subsoil-water which had percolated through from the river-bed (this was proved both by the gaugings and by the analyses, and had been already observed by the Rivers' Pollution Commissioners); that the effluent water was very satisfactorily purified, the nitrogen in solution appearing in the form of nitrates and nitrites—a sufficient proof that a considerable amount of oxidation goes on in the filter-beds.

Upon a comparison of the total nitrogen in solution in the sewage, in the effluent water, and in the subsoil-water (which was also analysed), it was found that the amount in the effluent water was almost exactly the amount that would be present in the sewage if diluted with the amount of subsoil-water (rather more than its own volume) with which the analyses and the gaugings showed it to have been diluted; that is to say, that a quantity of nitrogen equal to the amount in solution in the sewage escaped in the effluent water, and was lost (escaping, however, almost entirely in the oxidized and innocuous form of nitrates, &c.), the amount retained in the soil and by the plants being, therefore, equal to the amount in the suspended matters of the sewage. The effluent water was not quite so pure in the summer as in the winter: in the former case four fifths, and in the latter twelve thirteenths of the nitrogen contained in it was in the form of nitrates and nitrites.

The sewage was cooled by its percolation through the soil; in the winter from 48° F. to 46° F. (the temperature of the subsoil-water being 42° F.), and in the summer from 60° F. to 55° F.

The crops grown on the surface of the filter-beds were successful, and realized very good prices.

Irrigation.

In the First Report of the Committee a list of fifteen places where irrigation was practised was given, and a list of twelve more where it was contemplated; and it was stated that the areas used for irrigation varied from 0·4 of an acre to ten or twelve acres per thousand of the population, the distance of the land from the lowest outfall sewer of the town varying from 100 yards to upwards of a mile.

The general result was reported to be as follows:—"At most places the application of the sewage to land has been found to exercise a most beneficial influence on the condition of the streams and rivers receiving the drainage of the district."

"Generally speaking no objections appear to have been made to the application of sewage for irrigation; and where such objections have been urged on the ground that the application was offensive and injurious, they do not appear to have been supported by medical authority, and in several instances they have ceased. As regards the sanitary condition of these districts, it appears that in most cases the application of sewage for irrigation has not been attended with any apparent change; but there is said to be a marked improvement at Braintree."

"It is probable that . . . the application of liquid sewage to land would become a source of revenue to towns only under specially favourable circumstances, and that, in opposition to the opinions which have been somewhat hastily formed in certain cases, it will more frequently entail some amount of expenditure on the towns themselves. At the same time the benefit to land, and the improvement in the condition of rivers, to be realized by the mode of dealing with liquid sewage, can scarcely be matter of doubt or uncertainty any longer."

Of the 200 towns tabulated in the Second Report, 19 had recourse to irrigation either wholly or partially or in connexion with some precipitation process; and in one case, that of Leamington, irrigation was intended, and has since been carried out.

Owing to the fact that one of its members is the lessee of Breton's Farm, near Romford, in Essex, the Committee has had the advantage of making continuous investigations of the results of irrigation with this particular farm for the past three years, results which are detailed in the Annual Reports. Special investigations have also been made with the following results:—At the farms at Tunbridge Wells, where the sewage is applied to the surface of the land on the Catch-water System, and where under-drainage has not been systematically carried out (the drains which already exist having, in fact, been brought up to the surface to empty into the carriers), the purification of the sewage cannot be said to be satisfactory; for although a considerable dilution with subsoil-water takes place, the water which has passed over the land is still impure, and, moreover, contains scarcely any nitrates, thus showing that very little oxidizing action takes place.

The same result was found at the Reigate Farm at Earlswood, where the state of the effluent water was still more unsatisfactory; in fact, in one instance, it was found that sewage which had passed over the fields was actually stronger, except as regards actual ammonia (*i. e.* it contained more of the total solids in solution with more nitrogenous organic matters), than it was after passing over only the first of these fields—thus showing that the ground was so saturated with sewage, that any additional sewage passed on to it could "only concentrate itself by evaporation or by solution of matters in the upper layer of the soil." (Report III. pp. 181 to 185.)

These farms were again inspected in the following year. It was found that the effluent water was running clear and free from smell. No analyses were, however, made at this time. The crops included oats, beans, and wheat, as well as meadow-grass and Italian rye-grass, and seemed to be in a satisfactory condition; but no general system of subsoil-drainage had been commenced. A comparison was made in January 1871, during severe frost, of the results obtained in the purification of sewage at the three following farms:—Breton's Farm, near Romford, Beddington Farm, Croydon, and Norwood Farm. It was found that in the latter two cases, where the sewage was passed over the land on the Catch-water System, it was not satisfactorily purified, the nitrogen escaping in the effluent water being only partially in the state of nitrates and nitrites; while in Breton's Farm, where the sewage passes through the soil, the farm being in effect a large filter-bed, "(1) oxidation goes on in winter as well as in summer, and almost all nitrogen lost is lost in an oxidized and inoffensive form, and (2) this loss is very slightly greater in winter with a very strong sewage than in summer with a weaker one; so that sewaging in the winter would appear to entail no extra loss of manure."

It was also observed that while in summer sewage is cooled by percola-

tion through the soil, and almost always heated (sometimes considerably so) by surface-flow, as was observed both at Tunbridge Wells and at Earlswood (the temperature of the effluent water in the latter case being actually 5° F. higher than that of the sewage), in winter, on the other hand, the cooling which takes place is less with percolation through the soil than with surface-flow in both instances; so that "these results are favourable to percolation through the soil, as opposed to mere surface-flow, both in summer and winter. Percolation causes a considerable cooling in the summer, while in winter it does not cool the effluent water so much as surface-flow does."

These results induced the Committee to make the following distinct statement in their Third Report, p. 185:—"It may seem almost superfluous for the Committee, after so many years of general experience throughout the country, to argue in favour of the subsoil drainage of naturally heavy or naturally wet land with impervious subsoil for purposes of ordinary agriculture; but some persons have strongly and repeatedly called in question the necessity of draining land when irrigated with sewage; and the two farms at Tunbridge Wells, to a great extent, and more especially the Reigate Farm at Earlswood, have been actually laid out for sewage-irrigation on what may be called the 'saturation principle;' so that it appears to the Committee desirable to call attention to the fact, that if drainage is necessary where no water is artificially supplied to the soil, it cannot be less necessary after an addition to the rainfall of 100 or 200 per cent. But a comparison of the analyses of different samples of effluent waters which have been taken by the Committee from open ditches into which effluent water was overflowing off saturated land, and from subsoil-drains into which effluent water was intermittently percolating through several feet of soil, suggests grave doubts whether effluent water ought ever to be permitted to escape before it has percolated through the soil."

At Breton's Farm, where the sewage of the town of Romford, with a population of 6338 (a little more than two thirds of which only discharge their refuse into the sewers, the previous estimates having been all too high), is utilized upon 121 acres of land, there are special advantages for accurate investigation. The soil, which was very poor, consisting in many parts almost entirely of gravel (as will be seen by the analysis already quoted from the Committee's Second Report), was laid out in rectangular beds on the Ridge-and-Furrow System, the "beds" or "lands," each 30 feet in width, running at right angles to the main carriers which distribute the sewage. The sewage, when it arrives on the farm, is received in one of two tanks, where a deposit takes place and a scum forms on the surface. The liquid is run out between these into the pumping-well, and is raised by a pump "to a height of about 25 feet into iron troughs supported on wooden tressels, which convey the sewage to all parts of the farm, by discharging it either directly into the gutters or grips formed on the ridges of the 'lands,' and out of which the sewage is distributed right and left down the slightly inclined slopes of the lands, or, in the first instance, [into concrete carriers, raised by earth banks to a height intermediate between the height of the iron troughs and the level of the ground." (Report II. p. 62.) "About 85 acres of the farm, which are above the level of the tank, have been underdrained by pipe-drains 50 yards apart, and from 5 to 6 feet in depth, in such a manner that the water from the drains can be discharged into the sewage-tank if required in dry weather, or at pleasure into the river Rom."

This arrangement afforded excellent opportunities for the gauging of the effluent water.

In the Second Report will be found a detailed account of the crops grown and the prices obtained.

Some of the earliest experiments made by the Committee related to "the capacity of earth laid out in beds of 30 feet wide for the absorption of liquid." Three different kinds of gauges were used, and a time was chosen "when the land was in what may be considered an average state of moisture." From these experiments "it resulted that land in the state of moisture which existed on the 19th March [1870] and laid out in beds of 30 feet wide would only absorb, when consolidated, on the surface about 40 tons of liquid per acre, and when stirred to a depth of 9 inches on the previous day, about 90 to 110 tons per acre. By the word 'absorb' is meant that no more than the above quantities could be applied without the formation of puddles at the sides of the beds." (Report II. p. 69.) It was considered that 400 tons per acre was probably the largest quantity that had ever been applied in any one dressing, and that the assumption that the first dressing all over the farm was at the rate of 400 tons per acre, the second at that of 200, and the subsequent ones at that of 100 was probably not far from the truth.

In the Third Report, p. 175, will be found a summary of the results of the gaugings of the sewage and effluent water from June 12th, 1870, to July 15, 1871 (a period of 399 days). It appears that the average quantity of sewage received from the town per day was 1029 tons, to which something must be added for night-sewage which was allowed to run on to the meadows between the farm and the town. After the 15th of April, when the new tanks were completed and all the sewage received on the farm, the total amount was found to be 1262½ tons in the 24 hours, 621¼ tons of which came during the working day of ten hours, and the remaining 641¼ during the night of 14 hours. These quantities, when computed for a day and night of 12 hours each, give day-sewage 729 tons, night-sewage 533½.

The sewage as pumped contains a certain amount of effluent water that has been brought back into the tanks. The average amount of this diluted sewage pumped was 1182 tons per day. The effluent water discharged, as far as could be estimated, was about 513⅓ tons per day. The rainfall during the 399 days was 22·64 inches, equal to 2287 tons per acre.

The experiments on the temperature of the sewage and effluent water are very important. The temperature of these liquids is very uniform when compared with that of the air, "being lower during extreme heat, and higher during extreme cold." "The ranges and variation over the total period have been:—

"Atmosphere	28°·5	to	76°	=	47°·5 F.
Town-sewage	43	„	66	=	23
Sewage pumped	43	„	67	=	24
Effluent water	41	„	64	=	23"

In one week during a severe frost, "when the mean noonday temperature was 28°·5 F., that of the sewage pumped and effluent water was 43° F." (Report III. p. 176.)

The Fourth Report gave the results of the observations carried on from March 25, 1871, to March 24, 1872, both days inclusive; and gave a more special account of the analyses of the sewage and effluent water during that period. The analyses were made of average samples—that is to say, of samples taken in proportion to the rate of flow of the sewage at the times as indicated by the gaugings.

The general results were:—

Sewage from the town	416,787	tons.
Effluent water returned to the tanks	52,466	„
Therefore Diluted sewage	469,253	„
Of which, Amount utilized	385,291	„
Amount merely filtered	83,962	„

As to the composition of the sewage and effluent water, the average amount of nitrogen for 100,000 tons in the diluted sewage pumped was 5·529 tons; that in the effluent water 1·147.

As the total amount of diluted sewage was	380,277	tons,
And the total effluent water	195,536	„

it follows that "the proportion of nitrogen escaping in the effluent water to the total quantity applied is therefore ·1067, or about one tenth."

An estimate was also made of the amount of nitrogen recovered in the crops; the general result of the whole being that of 100 parts of nitrogen in the sewage pumped, 42 were recovered in the crops, 11 lost in the effluent water, and 47 not accounted for—that is to say, remaining in the soil or escaping into deeper subsoil-waters. (See accompanying Report.)

Some experiments were also made with the view of inquiring into the possibility of the distribution of entozoic disease by means of sewage-irrigation. Some "slime and mud" from the bottom and sides of carriers at Earlswood Farm was examined by Mr. M. C. Cooke, who found that it contained life of various kinds, especially Annelida, but did not detect any entozoic larvæ. The existence of this slime at the bottom of the carriers here was attributed by the Committee "to the fact that the subsoil is kept in a saturated condition by the want of underdraining;" and they were of opinion "that when land is thus saturated with sewage, certain atmospheric conditions exist which may be attended by malaria more or less injurious to health." (Report III. p. 182.)

Dr. Cobbold was requested by the Committee to examine, in conjunction with Professor Marshall and the writer, the carcass of an ox fed for two years on sewage-grown grass. It was found to be, as he reports, free from internal parasites of any kind. All the viscera, together with portions of numerous muscles, "with their associated areolar and aponeurotic coverings," were carefully examined. He observed that the conditions were favourable to this result, inasmuch as (1) the grass &c. was cut and carried, and the animal was not grazed on the farm; (2) the soil is very porous; (3) mollusca, so often the intermediary bearers of entozoal larvæ, were scarce; (4) the only mollusks found (a species of *Limnæa*) contained no cercarian larvæ; (5) the "flaky vegetable tufts" collected from the sides of the furrows contained "numerous active free *Nematodes*, but no ova of any true entozoon; (6) the sewage probably contained sufficient alcohol to destroy the larvæ. The Committee agreed with all these observations except the last.

The absence of mollusca is most remarkable, and with it must be associated the observations recorded by the Committee of the destruction of wireworms &c. by the sewage. Thus a crop of American oats was seriously damaged and in danger of being destroyed by the ravages of the *Oscinis vastator*, one of the smallest but most destructive of those grubs and wireworms which at times cause such injury to cereal crops in this country. Two heavy dressings of sewage were applied to this bed during two successive days, the result being that the grubs were entirely destroyed and the greater part of the crop saved. (Report II. p. 65.)

Again, at Tonbridge Wells "it was stated that a large field of turnips, being infested with the fly, was flooded with sewage, which drowned the fly and saved the crop, which is expected to turn out well but rather late."

So far, then, as actual facts at present show, "there is no evidence that entozoal forms of life are to be found on the farm at all in any stage of their existence, or in the flesh of an animal fed exclusively for 22 months on sewaged produce grown on the farm." (Report III. p. 189.) As far as the sanitary influence of sewage-farming is concerned, the Committee have returns from eight places where it is at work. In no instance has any disease whatever been traced, either among the labourers on the farm or among the inhabitants in the vicinity, or among the cattle, to the sewage-farm. In two instances it is reported that the health of the neighbourhood has improved, and in several that the land has very much improved in value, and the production of crops is much more certain. The note from Aldershot is, "Sanitary state of Camp and Barracks vastly improved. The land produces fair crops under sewage, which before produced nothing whatever."

Conclusions arrived at by the Committee.

I. All conservancy plans, including midden-heap and cesspool systems, dry ash- and dry earth-closets, pail-closets, &c., are quite incompetent as solutions of the general question of the removal of the refuse matters of a population.

Such plans deal with only a small part of the liquid manure; towns which resort to one of them require, therefore, to be sewered, and the sewage requires to be purified.

The manure produced is in all cases (except in that of simple pails or tubs where no extraneous materials are added) poor, and will only bear the cost of carriage to a short distance, taking into consideration the cost of collection. That produced by the dry earth system is, even after the earth has been used four times over, but little better than a good garden-mould. Such plans, moreover, all violate one of the most important of sanitary laws, which is that all refuse matters which are liable to become injurious to health should be removed instantly and be dealt with afterwards. With all these plans it is an obvious advantage on the score of economy to keep the refuse about the premises as long as possible; and the use of deodorants of various sorts, or even of disinfectants, proves that this is the case, and that these systems all depend upon a fallacious principle. They should therefore be discouraged as much as possible, and only resorted to as temporary expedients, or with small populations under exceptional circumstances.

II. The water-carriage system, on the other hand, is based upon a sound principle, that of removing all the refuse matters at once, and in the cheapest possible manner, by gravitation, and ought to be resorted to in all but the most exceptional cases.

The opinion of the Committee, that all sewers should be made of impervious materials, and that separate drains to dry the subsoil should be constructed where necessary, has already been most emphatically expressed.

The freest possible ventilation of sewers, house-drains, and soil-pipes, in order to prevent accumulations of foul air, is also essential.

With regard to the utilization of sewage, the Committee has come to the conclusion that the precipitation-processes that it has examined are all in-

competent, and necessarily so, to effect more than a separation of a small part of the valuable ingredients of sewage, and that only a partial purification is effected by them. Some of them may, however, be useful as methods of effecting a more rapid and complete separation of the sewage-sludge.

The upward-filtration process only effects a clarification of the sewage, and is therefore no solution of the question.

Weare's charcoal-filtration process, as carried on at Stoke-upon-Trent Workhouse, did not give satisfactory results, the effluent water being in effect weak sewage; an opportunity will, however, soon be given for an examination of this process in a modified form on a much larger scale at Bradford, and under more favourable conditions.

Intermittent downward filtration through soil has been shown at Merthyr Tydfil to afford a means of purifying the sewage under favourable conditions; but it cannot be said to be a method of utilization except to a very partial extent, as the investigations made by the Committee showed that the effluent water contained as much nitrogen as was originally in solution in the sewage, but mainly as nitric acid instead of as ammonia and organic nitrogen. There can be no doubt that the process would prove useful as an adjunct to irrigation, or where a sufficient amount of land for irrigation cannot conveniently be got.

By properly conducted sewage-irrigation a solution is afforded to the question of sewage utilization; it has already been stated that a precipitation-process, or some clarifying process, may be found useful. If such process, however, removes the phosphates from the sewage, it will, if employed for irrigation, require to be supplemented either by the use of the precipitate produced in the settling-tanks, or by that of some other manure supplying phosphoric acid.

In all instances it is essential that the land should be well underdrained, and that the sewage should all pass through the soil and not merely over it; otherwise, as has been shown, it will only occasionally be satisfactorily purified.

The catchwater, or, as the Committee has termed it, the supersaturation principle, is not defensible either on agricultural, chemical, or sanitary principles.

An irrigation-farm should therefore carry out intermittent downward filtration on a large scale, so that the sewage may be always thoroughly purified, while at the same time the maximum of utilization is obtained.

It is certain that all kinds of crops may be grown with sewage, so that the farmer can grow such as he can best sell; nevertheless, the staple crops must be cattle-food, such as grass, roots &c., with occasional crops of kitchen vegetables and of corn.

And it is also certain, from the analysis of the soil, that it becomes very much richer under sewage-irrigation, and that some of the manurial constituents of the sewage accumulate in it.

Cattle should be fed on the farm. The result would be a vast increase in the production of meat and milk, the great desiderata of the populations producing the sewage.

Thus the system of farming must be specialized and capital concentrated, the absence of which conditions has proved a great barrier to the satisfactory practical solution of the sewage question.

The Committee has not been able to trace any ill effects to the health of the persons living around sewage-farms, even when badly conducted; nor is there any proof whatever that vegetables grown thereon are in any way inferior to those grown with other manure. On the contrary, there is plenty

of evidence that such vegetables are perfectly suited for the food of man and beast, and that the milk given by cows fed on sewaged grass is perfectly wholesome. To give a recent example, Mr. Dyke, Medical Officer of Health of Merthyr Tydfil, states that since the abundant supply of milk from the cows fed on irrigated grass the children's mortality has decreased from 48, 50, and 52 per cent. of the total deaths to only 39 per cent., and that, so far from diarrhœa having been made more prevalent by the use of sewaged cabbages, "last year the Registrar-General called attention to the fact that diarrhœa was less prevalent in Merthyr than in any place in England and Wales;" and he expressed his belief in "the perfect salubrity of the vegetable food so grown."

With regard to the assumption which has been made that entozoic diseases would be propagated by irrigation, all the evidence that the Committee has been able to collect, and more especially the positive facts obtained by experiments, are against such an idea; and the Committee is of opinion that such diseases will certainly not be more readily propagated by sewage-irrigation than by the use of human refuse as manure in any other way, and probably less if the precaution be taken of not allowing the animals to graze, but always having the grass cut and carried to them.

Report of the Committee for superintending the Monthly Reports of the Progress of Chemistry, consisting of Professor A. W. Williamson, *F.R.S.,* Professor Frankland, *F.R.S., and* Professor Roscoe, *F.R.S.*

The Committee have much pleasure in reporting that, during this third year of their publication, the monthly reports of the progress of chemistry have given satisfactory evidence of increasing usefulness. Not only has their circulation in this country and abroad increased, but there is every reason to believe that they supply an important want to the progress of chemistry in this country, and will conduce to the advancement of the science.

The thanks of the Association and of science generally are due to the gentlemen upon whom devolves the labour of making these abstracts, and of thus bringing to a focus the rays of light which emanate from the various places where chemistry is cultivated.

On the Bradford Waterworks. By Charles Gott, *M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso.*]

In 1854 the "Bradford Corporation Waterworks Act" was passed. Under the power of this Act the Corporation purchased all the existing works, and were charged with the duty of providing the supply of water for the borough and surrounding districts.

At this time the old works supplied about half a million gallons of water per diem, a quantity altogether inadequate for the necessities of the inhabitants.

After obtaining their powers the Corporation put them into operation at once, and commenced the construction of the large system of works from which the town is now supplied.

Some of the reservoirs, conduits, and other works which are to form parts of the same system are not yet completed.

All the Bradford waterworks are gravitation works; there are no pumping-engines or other means employed for raising water from streams or wells. The water is collected at such levels that it can be conveyed directly into the reservoirs for storage and supply. The sources of supply which are available are therefore more limited in extent than would be the case if the water was lifted from some lower level; but, on the other hand, the water is more free from pollution and is softer and of better quality.

No filtering of any kind is required; the water is supplied directly from the reservoirs into the distributing mains. The reservoirs act as subsiding reservoirs, and are found to be quite sufficient to render the water clean and bright.

The district of supply of the Bradford Waterworks is not confined to the borough, but includes thirty-four of the surrounding towns and places, viz.:—

Addingham.	Heaton.
Adwalton.	Hundsworth.
Allerton.	Idle.
Apperley.	Liversedge.
Bingley.	Morton.
Birstal.	North Bierley.
Burnsal.	Pudsey.
Calverley.	Queensbury.
Clayton.	Saltaire.
Cleckheaton.	Shelf.
Denholme.	Shipley.
Draughton.	Silsden.
Driglinton.	Thornton.
Eccleshill.	Tong.
Farsley.	Wike.
Gildersome.	Wilsden.
Gomersal.	Windhill.

With an aggregate population at the present time of not less than 280,000.

The levels of the district of supply vary greatly, viz. from 200 feet above the sea at Apperley to 1200 feet above the sea at Queensbury, making a difference of 1000 feet of elevation to be covered by the distribution of the water. The supply is given in two separate services, called the high-level service and the low-level service, the high-level service being again divided and served by separate mains. All the places at a lower elevation than 500 feet above the sea are included in the low-level, and all the places above that height are included in the high-level service. The pressure of water in some of the distributing mains rises to upwards of 200 lbs. on the square inch.

The sources of supply for the low-level service lie to the north of Bradford in the valleys of the rivers Aire and Wharfe; various streams and tributaries of these rivers are taken into the reservoirs and conduits. The principal streams taken are the Sand-bed beck, Halton-gill beck, Joy beck, Berry-ground beck, Gill beck, Howgill beck, Barden beck, Hethness Gill, and the Marchup beck in the valley of the river Wharfe, and the Fish beck, Holden

beck, Swartha beck, Clough beck, Spinner beck, and the Judith-Cliffe beck in the valley of the river Aire. These streams receive the water from a drainage area of 9770 acres, 7550 acres being in the Wharfe valley, and 2220 acres in the Aire valley.

The average rainfall on these gathering-grounds is about 36 inches per annum.

There is no storage reservoir in the valley of the river Aire, so that that part of the gathering-ground cannot at present be fully utilized; the daily flow of the streams only can be taken, and none of the winter flow can be collected for summer use.

In the valley of the Wharfe there are two storage reservoirs, viz. the Barden reservoir and the Chelker reservoir.

The sources of supply for the high-level service lie to the west of Bradford in the valleys of the Denholme beck and the river Worth, both tributaries of the river Aire.

The principal streams taken are the Stubden beck and the Foreside beck in the Denholme valley, and the Bond Clough, Rag-Clough beck, Greenholes Clough, Hardnese Clough, Deep Dyke, Paul Clough, Sun-Hill Clough, Nan Scar beck, Holden Clough, Harden Clough, Stoney-Hill Clough, and Foster Dyke in the valley of the river Worth. None of the works in the Worth valley have been completed yet; up to the present time the high-level supply has been drawn entirely from the Stubden and Foreside becks. The drainage-area of these streams is 2700 acres, viz. 900 acres in the Denholme valley, and 1800 acres in the Worth valley.

The average rainfall is about 42 inches per annum, and the lowest level at which water is taken for supply is 1030 feet above the sea.

Nearly the whole of the gathering-grounds from which the water for supply is drawn are high moor lands, above the reach of any pollution from populated districts; they range in elevation from 600 feet to 1475 feet above the level of the sea.

The total acreage of the drainage-area exclusively appropriated for the supply of the town is 13,000 acres, viz.:—

Low Level.		
Wharfe valley	7550	
Aire valley	2220	9,770
High Level.		
Denholme valley	900	
Worth valley	1800	2,700
Old Works.		
Many Wells spring		530
Total Acreage		13,000

The water collected from these sources is conveyed to the town by means of covered stone conduits and large iron pipes. The length of the conduit from the Heaton-service reservoir at Bradford to the Barden reservoir is 18 miles, and from the Barden reservoir to the Sand-bed beck at Burnsal, the most distant stream taken to the north, 4 miles. The length of the iron main from the Horton-Bank reservoir to the Stubden reservoir at Denholme

is 5 miles, and of the conduit from the Stubden reservoir to the Bond Clough at Haworth, the most distant stream taken to the west, 4 miles.

The whole of the works so far mentioned are exclusively for collecting and supplying water for the use of the towns.

Other reservoirs with separate drainage-areas have been made for collecting and supplying compensation water to the various mills and streams which are affected by the taking of the town supply—viz. the Gumwith reservoir at Hartlington for giving compensation water for that which is taken from the streams in the valley of the river Wharfe, the Silsden reservoir at Silsden for the low-level works in the valley of the river Aire, the Hewenden reservoir at Hewenden for the old supply of the Many Wells spring, the Doe-Park reservoir at Denholme for the high-level works in the Denholme valley, and the Leeming and Leeshaw reservoirs at Oxenhope (now in course of construction) for the streams to be taken in the valley of the river Worth.

The extent, capacity, &c. of the several reservoirs are as follows, viz.:—

Supply Reservoirs.

Name.	Capacity.	Depth of water above outlets.	Length of embankment.	Greatest height of embankment.	Area of water when full.	Drainage-area.	Level above the sea.
	gallons.	feet	yards.	feet.	acres.	acres.	feet.
Low Level.							
Barden reservoir	440,000,000	60	750	96	66	2610	700
Chelker reservoir	250,000,000	36	333	45	56	1290	722
" " (west)	....	....	346				
Heaton reservoir (Service)	31,000,000	33	366	39	$8\frac{1}{4}$	....	523
High Level.							
Stubden reservoir	85,000,000	55	190	82	11	900	1028
Brayshaw reservoir ..	57,000,000	19	1090	38	13	....	975
Old Works.							
Chellow-Dean reservoir (upper)	50,000,000	44	120	55	8	Many Wells spring.	691
Do. (lower)	28,000,000	37	90	46	$5\frac{1}{2}$	530	640
Whetley-Hill reservoir (Service)	2,650,000	12	...	18	$1\frac{1}{6}$	....	518
Compensation Reservoirs.							
Gumwith reservoir....	634,000,000	66	233	83	94	7000	877
Silsden reservoir	230,000,000	78	187	94	25	2000	580
Doe-Park reservoir ..	110,000,000	52	170	60	20	1000	850
Hewenden reservoir ..	70,000,000	35	230	48	14	1000	687

The total quantity of water, exclusive of compensation water, which the entire scheme will yield when the reservoirs and conduits now being made

are completed, is ten millions of gallons per day, a quantity equal to 36 gallons per head for the population of the district of supply.

The sources of supply of these works would, however, if fully developed, yield more water than the quantity named; 700 acres of gathering-ground, on which there is a rainfall of 44 inches per annum, will yield one million gallons of water per day if a reservoir is made to contain 180 days' supply. With a rainfall of 36 inches per annum, the drainage-area would require to be about 900 acres to give the same quantity of water per day. The quantity of water to be impounded, 180 days' supply, 180,000,000 gallons, is equal to 11·4 inches in depth on 700 acres, and to 8·805 inches in depth on 900 acres, about one fourth of the total rainfall in each case. These quantities may vary, however, to some extent with the character of the gathering-ground; sometimes it happens that there are large springs within the drainage-area, whilst in other cases the ground may be so absorbent that part of the water may pass down to springs below the level of the works.

The supply is also dependent upon the distribution of rain throughout the year; if the rain falls in heavy floods with a long period of drought, so much of the fall cannot be utilized as during years when the rain is more equally distributed.

In determining the value of any given area of gathering-ground after the average rainfall is ascertained, one fourth is to be taken off to arrive at the quantity for dry and exceptional years, one third of the remaining quantity is then to be deducted for loss by evaporation, absorption, discoloured and turbid water, and unmanageable floods. These quantities show that only one half of the total average rainfall can be collected and used. These quantities and particulars, however, apply only to gravitation works in districts similar to those in which the Bradford works are situated.

The Bradford reservoirs are formed in the manner usually adopted for large works—*i. e.* by embankments made across the valleys, such sites being almost the only practicable ones where reservoirs could be made of sufficient size for the large quantities of water to be collected.

The mode of construction adopted for such reservoirs is to make the embankments of earthwork, the earth being excavated from the site of the reservoir itself. In the middle of the embankment a vertical core or wall of puddle is made, to render it impervious. This puddle-core must be continued to such a depth that the water cannot pass under it; and it must also be continued so far into the sides of the hills which form the valley, that the water cannot pass round the ends.

The strata underlying the site of the reservoir are not always regular; in some cases the bottoms of the valleys have been raised by drift many feet in thickness. It is necessary to find some stratum or some number of strata which together will make an impervious bottom, and which underlie nearly the whole of the site, and to continue the puddle-work of the embankment (by means of open-cut trenches) into them, so as to form a complete basin or inclosure within which the water is to be contained.

It is necessary in some cases to continue the puddle-trenches from the ends of the embankment up the sides of the valley to some point where the dip of the measures brings the impervious stratum to the height required for the surface of the water when the reservoir is full: advantage is also to be taken of faults and dislocations in the natural strata; in this district these faults are nearly always impervious, and they are sometimes of great service in reservoir works.

In making the deep trenches for the puddle-work, it frequently happens

that springs of water are met with, and great difficulties are sometimes experienced in dealing with them. If the springs run in from the sides of the trench at a level above the stratum on which the puddle is to rest, they do not constitute any permanent difficulty; the water may be pumped out of the trench whilst the work is in progress, and may be gradually turned back with the puddle, which is put into the trench as the work proceeds. If, however, a spring rises from the bottom of the trench, it cannot be disposed of in that way. It must be built round in some safe manner by concrete or stonework and collected, so that it can be brought up in an iron pipe in the work, or conveyed to one end of the puddle-trench and discharged at the surface of the ground clear of the embankment. Springs in the ground which is to form the bottom of the reservoir do not indicate that the site is not a good one, but generally the contrary; and they sometimes show where the embankment can be placed with the greatest advantage.

The existence of the springs may show that there is some impervious material lying across the valley somewhere below the line along which they issue; and on this impervious material, and below the springs, it is probable the embankment may be most easily formed: at any rate, the springs show the line immediately above which it would not be desirable to place the embankment.

The works for admitting streams into reservoirs are of several kinds. In cases where the whole stream is taken, a pool or lodge is made by a dam placed across the stream at the head of the reservoir. This dam arrests the flow of the stream, and gives time for any solid matter carried on by the water to fall, and to a great extent saves the reservoir from being silted up; the solid deposit is caught in the lodge, from which it can be easily removed. The size of the lodge can be regulated to suit the character and requirements of each case.

In cases where turbid or coloured water is not to be taken, side channels for carrying floods past the reservoirs must be made; and the usual mode of admitting the streams is by what are called leaping-weirs. This contrivance consists of a weir built across the stream, to stop the water and cause the water to flow over the conduit which is intended to receive it and carry it to the reservoir. The conduit intended to receive the water is built across the stream inside the weir, and a long narrow opening is made through the crest of the weir along the top of the conduit. The weir on one side of this opening is made a step lower than it is on the other side, and the stream in passing has to fall down this step. When the quantity of the stream is small, it will run close over the edge of the step and fall through the narrow opening into the conduit below; but when the stream is swollen and large, it will run with greater velocity, and will leap from the top of the step over the opening and pass away down its original course.

The size of the opening can be adjusted so as to take any given quantity of water required from the stream. It is self-acting, so far as regards the passing of dangerous floods; but it is not altogether so, so far as the rejection of turbid water is concerned. It does, however, make a selection of water to some extent, as it usually happens that when the water is most turbid and during sudden storms, the streams would be so much increased that they would overleap the opening through the weir, and so pass off without entering the works.

Another mode of taking in streams and obtaining only clean water from them, is to construct a filtering-conduit under the bed of the stream to receive the water before it is admitted into the reservoir. These filtering-conduits

are formed by making an ordinary brick or stone channel a few feet below the level at which the stream is to be received. The channel is in section of the shape of a letter U; over the top open grating or stonework is placed, in such a manner as to allow water to flow freely through it. The ground at the sides of the channel is made solid and impervious up to the level of the side walls. Over the channel, and for any convenient breadth on both sides of it, broken stone, gravel, or other filtering media are placed, through which the water has to run before it can find its way into the conduit. In this way any solid matter can be caught and separated from the water, and the water can be obtained in the reservoir fit for immediate use. The water in the reservoir is not liable to be discoloured by any sudden flow of turbid water during heavy rains or thunder-storms, as the excess of water beyond the quantity which can pass through the filter will flow off down the side and waste channels made for the purpose.

This mode of admitting water to conduits and reservoirs is entirely self-acting, does not require attention during storms, and the dirt on the filters will be carried away by floods or can be easily removed.

The works for drawing water out of reservoirs are not without difficulties of their peculiar kind. The mode usually adopted is to make a tunnel or culvert through the embankment at the lowest level at which the water is required to be drawn; and at the middle of this culvert, but a little within the puddle-core, to erect a strong shaft or well in which to place the valves for drawing off the water. The rods and apparatus for opening and shutting these valves are taken up the shaft to the top of the embankment. This mode of construction is attended with many difficulties, and often leads to breakage of the work, and to consequent leakage of water from the reservoir. This breakage arises from unequal settlement; for if the foundations of the shaft are made rigid and secure, the shaft itself stands, whilst the tunnel or culvert on both sides of it cannot be kept so rigidly in position, and fractures consequently take place, generally on both sides of the vertical shaft. The settlement under the embankment is also necessarily unequal, the middle and highest part being much heavier than the inner and outer parts. The settlement of the embankment is often both vertical and lateral, on account of the spreading of the foundation work of the embankment, which sometimes tears the masonry asunder, and so increases the injury caused by the unequal settlement round the vertical valve-shaft. To avoid these difficulties, the tunnel or culvert is now frequently made in the solid ground at the side of the valley, some distance from the middle of the embankment, and where the disturbance caused by the unequal settlement is not likely to reach.

When the water is drawn through these valves in the midst of the embankment, great vibration is caused by the force of the water passing out. This vibration is liable to increase the settlement of the heavier parts of the embankment for some considerable distance round the outlet works, especially when the substrata are of a compressible character, and may cause settlement of the work which would not otherwise occur.

These difficulties have been provided against in some of the later Bradford waterworks by placing the outlet valves at the outside of the embankment, and conveying the water through the outer half of the culvert in an iron pipe. The vertical valve-shaft for the rods and apparatus for opening the valves are by this means rendered unnecessary, and the unequal settlement and injury caused by vibration are altogether avoided. This mode of construction has so far been found to work with advantage; the valve and outlet

works are easily accessible for examination and repair, and are less costly than the mode previously described.

Overflow and waste channels also require special attention in their construction, on account of the difficulty which is sometimes experienced of passing flood-water from sudden and unusual storms.

The great height from which the water has to be conveyed renders it difficult to deal with. The water has to be received above the reservoir, and conveyed down to the stream in the valley below, a height in some cases exceeding 100 feet. During this fall it attains considerable velocity, and passes with great force.

The mode of construction which has been adopted in some cases is to form the waste channel in such a way that the water shall be let down by a series of short vertical falls, the bottom of the channel being so made as to give no increase of velocity to the water as it flows along. These falls are formed by walls built across the bottom of the channel, circular or otherwise, on plan, the tops of the walls being in every case higher than the bottom of the channel—the effect of these walls being that the velocity acquired by the water in passing one fall is not continued and increased at the next, the water held back by the wall forming a pool, which simply overflows at the fall next below. These pools have the further effect of protecting the stonework of the bottom of the channel from the force of the water falling upon it, and the water is made to receive its own force when passing along the work.

The importance and value to Bradford of a supply of soft water is very great, a large proportion of the water being used far trade purposes, for washing wool, and for dyeing, &c., for which hard water would be of much less value.

The town has had the benefit of a constant service at high pressure for some years past, and has become rather exacting and particular.

The intermittent supply of many large towns would be altogether unsatisfactory here, after the constant supply under high pressure to which the inhabitants have become accustomed.

A new use of water is gradually being introduced. The water is being taken direct from the street mains, and employed for working water-pressure engines. These engines are becoming numerous, and are likely to be extensively used for working warehouse cranes, and for many other purposes where only light work is required. They appear to have many advantages as compared with steam, where one or two horse-power at most is wanted: they are always ready for work, they require no special buildings or furnaces, they can be readily applied in any premises without structural alterations and without increasing the danger from fire, and are very simple and easy to work.

The prices at which water is sold for trade are very low. It is sold by measure; and the prices range from 1*s*. down to 2*d*. per 1000 gallons.

The value of the waterworks to the town has been very great. The trade of the district could not have been developed to the same extent without them, and the whole of the property of the town is increased in value by them.

Report of the Committee appointed to consider the possibility of Improving the Methods of Instruction in Elementary Geometry, the Committee consisting of Professor SYLVESTER, Professor CAYLEY, Professor HIRST, Rev. Professor BARTHOLOMEW PRICE, Professor H. J. S. SMITH, Dr. SPOTTISWOODE, Mr. R. B. HAYWARD, Dr. SALMON, Rev. R. TOWNSEND, Professor FULLER, Professor KELLAND, Mr. J. M. WILSON, *and* Professor CLIFFORD (*Secretary*).

UNTIL recently the instruction in elementary geometry given in this country was exclusively based upon Simson's modification of the text of Euclid. Of late years, however, attempts have been made to introduce other text-books, agreeing with the ancient *elements* in general plan, but differing from it in some important details of treatment. And, in particular, the Association for the Improvement of Geometrical Teaching having considered the whole question with great labour and deliberation, is engaged in the construction of a syllabus, part of which is already completed. The Committee had thus to consider, *first*, the question of the plurality of text-books; *secondly*, certain general principles on which deviation from the ancient standard has been recommended; and, *thirdly*, the Syllabus of the Geometrical Association.

1. *On the Plurality of Text-Books.*

It has already been found that the practical difficulty of examination stands in the way of allowing to the geometrical teacher complete freedom in the methods of demonstration and in the order of the propositions. The difficulty of demonstrating a proposition depends upon the number of assumptions which it is allowable to start from; and this depends upon the order in which the subject has been presented. When different text-books have been used, it thus becomes virtually impossible to set the same papers to all the candidates; and in this country at present teaching is guided so largely by the requirements of examinations, that this circumstance opposes a serious barrier to individual attempts at improvement. On the other hand, the Committee think that no single text-book which has yet been produced is fit to succeed Euclid in the position of authority; and it does not seem probable that a good book could be written by the joint action of selected individuals. It therefore seems advisable that the requisite uniformity and no more should be obtained by the publication of an authorized Syllabus, indicating the order of the propositions, and in some cases the general character of the demonstrations, but leaving the choice of the text-book perfectly free to the teacher; and the Committee believe that the authorization of such a syllabus might properly come from the British Association.

2. *On some Principles of Improvement.*

The Committee recommend that the teaching of Practical Geometry should precede that of Theoretical Geometry, in order that the mind of the learner may first be familiarized with the facts of the science, and afterwards led to see their connexion. With this end the construction in practical geometry should be directed as much to the verification of theorems as to the solution of problems.

It has been proposed to introduce what are called redundant axioms—that is to say, assumptions whose truth is apparently obvious, but which are not

independent of one another. For example, if the two assumptions were made that two straight lines cannot enclose a space, and that a straight line is the shortest distance between any two of its points. It appears to the Committee that it is not advisable to introduce redundant axioms, but that all the assumptions made should be necessary for demonstration of the propositions and independent of one another.

It appears that the Principle of Superposition might advantageously be employed with greater frequency in the demonstrations, and that an explicit recognition of it as an axiom or fundamental assumption should be made at the commencement.

The Committee think also that it would be advisable to introduce explicitly certain definitions and principles of general logic, in order that the processes of simple conversion may not be confounded with geometrical methods.

3. *The Syllabus of the Geometrical Association.*

The Association for the Improvement of Geometrical Teaching has issued (privately) a syllabus covering the ground of the first three books of Euclid and the doctrine of proportionals. The Committee are of opinion that this Syllabus is decidedly good so far as it goes, but they do not wish to make a detailed report upon it in its present incomplete state. When it is finished, however, they will be prepared to report fully upon the merit of its several parts, to make such suggestions for revision as may appear necessary, and to discuss the advisability of giving to it the authority of the British Association. For this purpose the Committee request that they may be reappointed.

Interim Report of the Committee appointed for the purpose of making Experiments on Instruments for Measuring the Speed of Ships, &c.

YOUR Committee have to report that, owing to the various engagements of the members, it has been possible to hold only one meeting during the past twelve months.

At this meeting it was resolved to request the loan of instruments of each of the pressure and other logs to be experimented with, and also to endeavour to obtain the use of a vessel whereon to carry out the experiments.

Your Committee have much pleasure in stating that three instruments have now been kindly placed at their disposal, as well as a steam-launch for conducting the experiments.

Your Committee, if reappointed, trust that some actual results may be anticipated during the next twelve months.

No expense has been incurred, and no part of the grant of £50 has been drawn.

Report of the Committee, consisting of Dr. CRUM BROWN, Mr. J. DEWAR, Dr. GLADSTONE, Prof. A. W. WILLIAMSON, Sir W. THOMSON, *and* Prof. TAIT, *appointed for the purpose of Determinating High Temperatures by means of the Refrangibility of the Light evolved by Fluid or Solid Substances. Drawn up by* JAMES DEWAR, *Reporter.*

IT is well known that as the temperature of a solid is gradually increased, the refrangibility of the emitted light increases likewise; and as the result we find red light emitted first, and gradually the other coloured rays appear until we reach the ultra-violet rays. This correlation between refrangibility and temperature was first experimentally proved by Draper*; and it would be a result of great importance to determine accurately the law of growth of refrangibility with temperature. If this could be achieved, a very easily applied and accurate pyrometer could be made of the ordinary spectroscope.

There are various difficulties, however, that beset this investigation at the outset. First of all, the rapid growth of the new rays confines the observations within narrow limits of temperature; secondly, the want of equal sensibility of the eye for rays of all wave-lengths; and, thirdly, the interference of diffused light preventing exact definition. It thus appears to be futile to attempt or even expect accurate observations in these circumstances through registration by the human eye, although, on first considering the subject, it appears to be a very easy matter. Finding no means of overcoming these difficulties, unless by the use of complicated apparatus, involving the use of rock-crystal prisms and lenses or fine gratings and the employment of photographic registration, requiring time and thought previous to execution, a series of observations have been made in the mean time on the increase of radiation with temperature, an inquiry of vital importance with regard to this subject.

Becquerel, in his treatise on Light called 'La Lumière,' has detailed a great number of observations on the growth of luminous intensity with increasing temperature. From these experiments he infers that "the differences between the logarithms of the luminous intensities are proportional to the differences of temperature," proving that an exponential function of the form

$$I = a(e^{b(T-\theta)} - 1),$$

where I is the luminous intensity, T the temperature of the body, θ the temperature at which the special ray begins to be evolved, a and b constants, and e the base of the logarithms adopted. The values of a and b, as deduced from the experiment, for the red ray are respectively 0·00743 and 0·005014. The above formula gives equally the growth of total luminous intensity if we take θ as 500° C., that point at which the light-rays begin to be evolved, and a and b as now having the respective values of 0·12053 and 0·00764. From the last formula Becquerel gives the following values of the total luminous intensity of a solid substance at different temperatures, stating it is probable the above law does not hold above 1200° C.:—

* Phil. Mag. 1847.

Temperature.	Total luminous intensity.
916 (fusion of Ag)	1
1000	4·37
1037 (fusion of Au)	8·38
1100	25·41
1157 (fusion of Cu)	69·26
1200	146·92
1500	28900
2000	191,000,000

From the similarity of these formulæ with Dulong and Petit's law of heat-radiation, Becquerel regards them as being confirmed by analogy. The determinations of the temperatures in his experiments were all deduced from the intensity of the thermoelectric current of a platinum-palladium junction, and the luminous intensities were determined by means of a photometer based on double refraction.

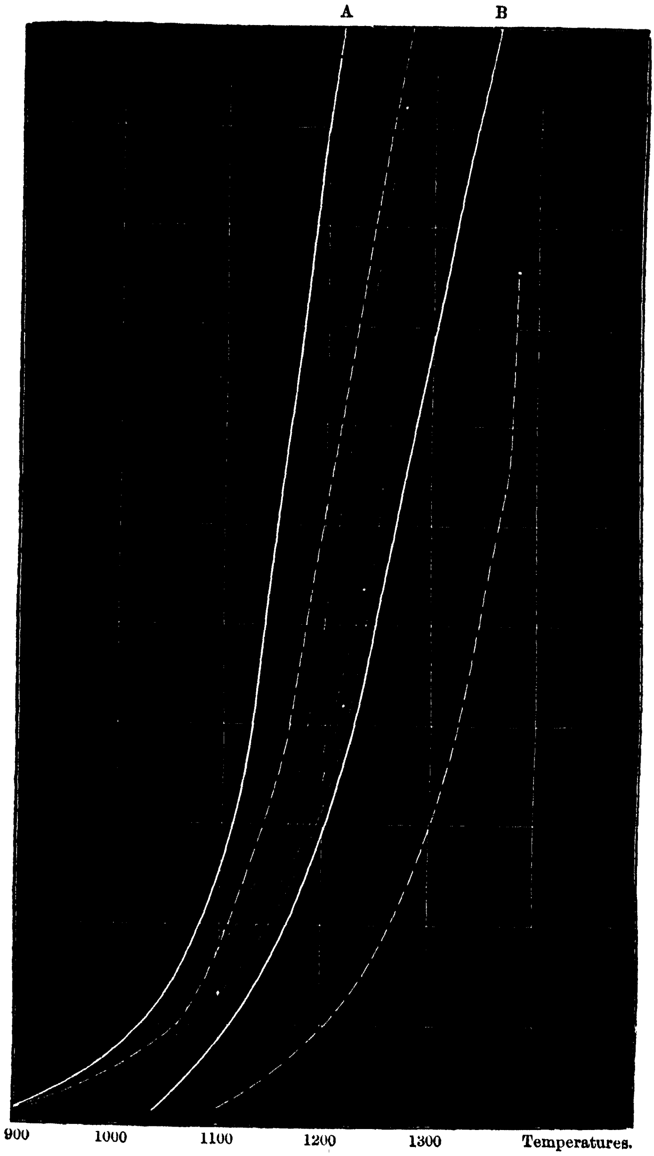
The observations made in connexion with this Report on the increase of total luminous intensity have been conducted similarly to those detailed by Draper in the Philosophical Magazine for 1847. The apparatus has been modified so as to be more conveniently employed, and the experiments made were found on being tabulated to be very well expressed by the following empirical formula:—

$$990+n\,46=n^2\,\mathrm{I},$$

where I is the luminous intensity, and $990+n46°$ is equal to the total temperature—that is to say, above the temperature of 1036° C., by which time all the luminous rays may be considered present; the intensity is a parabolic function of the temperature. The curve of increase is therefore a very acute parabola. The diagram, p. 463, contains the curves of Becquerel, both for homogeneous rays and for white light, and also the curve given by the above formula. It is evident the rate of growth of the total luminous intensity is very much slower than that obtained by Becquerel. The curve resembles the rate of growth obtained from the homogeneous rays in his observations, although all his curves begin more slowly and finish with far greater rapidity. This doubtless depends on the thermometric degrees diminishing rapidly with higher temperatures, according to his plan of measurement; but the great variation in the curves when taken, even for the same kind of ray, shows that little reliance can be placed on the results.

As the observations on increase of luminosity above 1000° C. can only be carried on for a range of 500° C. with the expansion of platinum, it was very essential that some comparison between the results of the empirical law given above and actual observation should be made at higher temperatures. For this purpose, a series of observations were made as to the relative light-intensity of lime heated to a temperature of 2000° C. in the oxyhydrogen flame, and the same substance at the boiling-point of zinc, temperature 1040° C. The following plan was adopted in making observations:—A square pencil of lime, four or five millimetres on the side, and of a length of 50 millims., was supported horizontally, and the inner cone of a powerful oxyhydrogen flame was made to play on a smooth cross section of the pencil. The light emitted from this perpendicular surface had to pass through a small circular aperture into an adjoining dark chamber for the purpose of comparison with the light emitted from an equal surface of lime, the temperature of which was near the boiling-point of zinc. In order to get a temperature maintained near 1000° C., I have adopted the following method:—A piece of platinum of an equal surface

Curves of Luminous Intensity.



A. Becquerel's curve. Total luminous intensity.
B. Author's curve. Total luminous intensity.
Thin and broken curves. Becquerel's homogeneous rays.

with that of the radiating lime, and of a thickness of 2 or 3 millims., was supported by means of a platinum wire in the flame of a good Bunsen burner, the position in the flame having been found by experiment to maintain the

mass at near the temperature required. This latter fact was ascertained by finding the amount of heat the platinum emitted when thrown into a calorimeter containing a known quantity of water. As the amount of heat emitted was very small, special precautions had to be taken in guarding the calorimeter and in getting the mass of platinum transferred. The calorimeter, containing about 100 grammes of water, was floated in a cistern (having been previously placed in the middle of a tin cylinder, leaving an annular space between), and so loaded that the water in the calorimeter was sunk to the level of the water in the cistern. The Bunsen burner was placed in a tin vessel loaded with shot, so as to give a flame the upper half of which was above the level of the water in the cistern. By this means constancy of temperature was maintained, and the results agreed closely together. It is easy to be convinced that a mass of platinum like that employed, radiating freely, is rarely heated above a temperature of 1100° or 1200° C. Comparisons were made between platinum in the Bunsen burner and lime in the oxyhydrogen flame, and also between lime in both.

The photometer employed for comparing the lights was on the principle of that recommended by Bunsen. A wooden box, about 8 inches long, 4 inches broad, and 3 inches deep, containing several diaphragms with circular apertures, thoroughly blackened in the interior, and having the aperture of the middle diaphragm covered with a piece of Swedish filter-paper, marked with one or two circular spots of paraffin, was employed to exclude extraneous light and to obtain good definition. By this means it is possible to obliterate completely the spot of paraffin, and thus gain greater confidence in the results.

From the mean of a great number of experiments made in this way, the luminous intensity at about 2000° C. is from 500 to 550 times that at 1040° C. The calculated amount given by the above formula for the exact temperature of 2000° C. is 484 times that at the lower temperature. According to the formula of Becquerel, it would be about 24,000,000 times that at the lower temperature. This empirical law, therefore, gives with considerable approximation the luminous intensity up to a temperature of 2000° C.

Total Radiation.—If the law of Dulong and Petit for the velocity of cooling was true for temperatures above the range of the actual observations made in support of the law, the amount of heat radiated per unit of time would be found by multiplying the velocity of cooling at the temperature considered into the specific heat at that temperature and into the weight of the substance. From this may also be calculated the amount radiated per unit of surface. In fact, for the same substance the relative quantities of heat evolved at two different temperatures would be to each other as the velocities of cooling if the specific heat and the emissive power remained constant. This would give an extraordinarily rapid rate to the growth of total radiation. For instance, taking the temperatures of 2000° C. and 700° C., we find, according to Dulong and Petit's law,

$$\frac{Q_1}{Q_2}=\frac{a^{2000}}{a^{700}}=a^{1300}=21,545,$$

where a is the constant 1·0077.

Thus a substance radiates at a temperature of 2000° C. 21,000 times as much heat per unit of time as it does at a temperature of 700° C.

In order to compare the total radiation as given from the law of Dulong and Petit with that of actual experiment, a series of observations were made, and the total heat evolved registered by the use of Pouillet's pyrheliometer. For this purpose, a spherical ball of lime, 8 millims. in diameter, was formed

by careful filing and polishing on the end of a narrow pencil of the same substance. This little knob of lime was then gradually heated, carefully turning it round, up to incipient fusion in the oxyhydrogen flame, so as to allow contraction to take place. With care in this way, it is possible to get a very uniform sphere having a surface of about one square centimetre. The pyrheliometer was filled with bisulphide of carbon, for the purpose of registering minute alterations of temperature. The experiments were made at two distinct temperatures, viz. at a low visible red heat and at the maximum temperature of the oxyhydrogen flame. The mean of these experiments has given, for radiation per square centimetre per minute at about 700° C., from 20 to 25 gramme-units per minute, and at 2000° C. maximum temperature from 2000 to 2500 gramme-units—the ratio of the amounts being as 1 to 100, very different from the calculated result. The law of Dulong and Petit, therefore, gives a far too rapid increase for the total radiation; and if we assume the law to be true in order to define temperature, the results arrived at are always too low.

If the total amount of radiation at different temperatures is tabulated, using a thermoelectric pile and an apparatus similar to the one employed for light-intensities, it is found that the curve of increase may be very accurately represented by a parabolic curve. The empirical formula of this curve is

$$580^\circ + n3 \times 46^\circ = n^2 \mathrm{R},$$

where R is the total radiation at 668° C., and $580^\circ\mathrm{C.} + n3 \times 46^\circ\mathrm{C.}$ is equal to the temperature of the substance. If we calculate the total radiation from the above formula at 2000° C. as compared with that at 668° C., it is in the ratio of 1 to 112. Regarding these comparisons, they appear fairly within the limits of experimental errors. We would anticipate that a similar law would hold alike for heat-rays and light-rays.

Assuming these laws to be approximately correct, it is interesting to find what hypothetical temperature in the case of a solid or fluid substance would correspond with the luminosity and total radiation from the sun.

From the experiments of Fizeau and Foucault*, the luminous intensity of the sun is found to be 146 times that of the lime-light. A temperature of 13,000° C., according to the formula given above, would give 144 times the luminous intensity at 2000° C.

From the observations of Pouillet, the total radiation from 1 square centimetre of the sun's surface in 1 minute was 85,000 units, and cannot well exceed 100,000 units. At a temperature of 11,000° C., according to the above formula for total radiation, the amount would be 50 times that at 2000° C. Now we have found above that a square centimetre of lime at 2000° C. emits 2000 gramme-units per minute, so that a temperature of 11,000° C. would be sufficient to evolve 100,000 gramme-units, as much heat as is produced by the sun. The recent observations of Soret ('Bibliothèque Universelle,' 1872) prove that the total radiation of the sun is between 50 and 60 times that of lime heated to 2000° C. in the oxyhydrogen flame. The estimate of 100,000 gramme-units per minute from the sun is therefore not too great, seeing that it is just 50 times the amount actually emitted by observation at 2000° C.

Experiments with Electric Arc.—The experiments formerly detailed to the Association on the specific heat of carbon up to a temperature of 2000° C. naturally suggested the attempt to define by observation the temperature of

* Ann. de Chim. et de Phys. 1844.

the electric arc, by determining the amount of heat evolved when pieces of carbon, heated between the poles, are thrown into a calorimeter. When a fifty-cell Bunsen's battery is employed, it is found that 1 gramme of carbon evolves as a maximum 850 units of heat when cooled from the temperature it acquires between the poles of the battery. This quantity of heat only corresponds to a mean temperature of 2000° C. in the heated carbon when the great increase in the specific heat of carbon is taken into account. In the experiments made with the battery, no precaution was taken to prevent the cooling of the piece of carbon between the poles from radiation, and consequently the substance never attained a uniform temperature. This fact is easily proved on examining the appearance of the carbon after use, when the substance is only changed into graphite in a few points. That temperature at which carbon changes into graphite may, in experiments of this kind, be used as a fixed point.

The luminous intensity of the electric arc, according to Fizeau and Foucault, is from 34 to 56 times that of the lime-light when 46 cells are employed, of small or large surface. According to the empirical formula previously given, this would correspond to a temperature of from 7000° C. to 8500° C.

In the course of the experiments with the battery, several determinations of the total radiation were made by the pyrheliometer. The mean of the observations, which were remarkably constant, corresponds to a radiation of 7100 gramme-units per minute, being equivalent to a solution of 4·5 grammes of zinc per minute. A concave parabolic mirror 1 yard in diameter, exposed perpendicularly to the sun's rays in this country, concentrates as much radiant energy as a 50-cell Grove's battery of large surface.

On a Periodicity of Cyclones and Rainfall in connexion with the Sun-spot Periodicity. By CHARLES MELDRUM.

[A communication ordered by the General Committee to be printed *in extenso.*]

AT the Brighton Meeting (1872) it was stated that the cyclones of the Indian Ocean, between the Equator and lat. 25° S., were much more frequent in the maxima than in the minima sun-spot years.

Since that time the subject has been more fully examined, and I now beg to present a Catalogue of all the cyclones known to have occurred in that part of the world during the last twenty-six years. The Tables given last year contained only cyclones of sufficient violence to dismast or otherwise disable vessels at sea, whereas the accompanying Catalogue gives all the cyclones of force 9 to 12—that is, "strong gale" to "hurricane."

The observations for the years 1847 to 1850 are probably not so complete as those for the subsequent years, during which the Meteorological Society of Mauritius made it a special duty to collect storm statistics. Still it is evident that not only the years 1860 and 1872, but also the year 1848, were remarkable both for the number and violence of cyclones, while the years 1856 and 1867 were quite the reverse.

By taking the number of cyclones in each maximum and minimum sun-spot year and in each year on either side of it, so as to form maxima and minima periods of three years each, we obtain the results given in the last column of the following Table, showing that during the maxima periods 1848 to

1850 and 1859 to 1861 the number of cyclones was 65, whereas in the minima periods 1855 to 1857 and 1866 to 1868 it was only 34, or little more than one half. In 1856 there was only one hurricane of small extent, and in 1867 no hurricane at all. Indeed it is doubtful whether several of the cyclones in the latter year, classed under "storms," should not have been classed under "whole gales" and "strong gales."

The Number of Cyclones in each year, from 1847 to 1873.

	Years.	Number of hurricanes.	Number of storms	Number of whole gales.	Number of strong gales.	Total number of cyclones.	Number of cyclones in maxima and minima periods.
	1847.	5	0	0	0	5	
Max.	1848.	6	2	0	0	8	
Max.	1849.	3	2	3	2	10	26
Max.	1850.	4	3	1	0	8	
	1851.	4	2	1	0	7	
	1852.	5	0	3	0	8	
	1853.	1	1	5	1	8	
	1854.	3	1	0	0	4	
Min.	1855.	3	2	0	0	5	
Min.	1856.	1	0	2	1	4	13
Min.	1857.	2	1	1	0	4	
	1858.	3	1	3	2	9	
Max.	1859.	3	2	6	4	15	
Max.	1860.	7	4	2	0	13	39
Max.	1861.	5	2	2	2	11	
	1862.	4	2	2	2	10	
	1863.	5	2	1	1	9	
	1864.	2	2	1	0	5	
	1865.	2	2	3	0	7	
Min.	1866.	1	4	2	1	8	
Min.	1867.	0	4	2	0	6	21
Min.	1868.	3	2	2	0	7	
	1869.	3	1	3	2	9	
	1870.	2	1	5	3	11	
Max.	1871.	3	2	3	3	11	
Max.	1872.	6	5	1	1	13	36
Max.	*1873.	4	5	3	0	12	

* To 31st May.

As during the last twenty-two years information respecting the cyclones of the Indian Ocean has been carefully and systematically collected and tabulated, I believe that the results now given are substantially correct; and it seems to me that they point to a close connexion between sun-spots, or solar cyclones, and terrestrial cyclones, or what might be called earth-spots by an observer on another planet.

Most of the severest cyclones have been already traced, and the others will also be traced. When this shall have been done, an attempt will be made to express numerically the amount of cyclonic area and cyclonic force for each year. The Catalogue gives little more than the number of cyclones; but, from what is already known, there is little doubt that their extent and force were also far greater in the maxima than in the minima years.

Being desirous of extending the investigation as far back as possible, I have

been examining lists of former hurricanes; and it is interesting to find that the evidence from this source strongly corroborates the conclusions deduced from the observations of the last twenty-six years. From a "Chronological Table" published in the Mauritius Almanac of 1869, we obtain the following list of Mauritius hurricanes:—

Years.	No. of hurricanes.	Years.	No of. hurricanes.
1731	1	Bt. forward	12
1754	1	1818	1
1760	1	1819	2
1766	1	1824	2
1771	1	1828	1
1772	1	1829	1
1773	1	1834	1
1786	1	1836	1
1806	1	1844	1
1807	2	1848	1
1815	1	1850	1
	12	Total	24

Probably the above list gives only the hurricanes that were remarkable from their destructive effects in the island; and much stress should not be laid on observations taken at a single station. Nevertheless it is rather suggestive that out of the twenty-four hurricanes mentioned, seventeen fall within, or very nearly within, maxima sun-spot periods, and only seven within minima periods. Thus:—

Maxima years.	No. of hurricanes.	Maxima years.	No. of hurricanes.	Minima years.	No. of hurricanes.
1760.	1	Bt. forward	9	1731.	1
1771.	1	1818.	1	1754.	1
1772.	1	1819.	2	1766.	1
1773.	1	1828.	1	1824.	2
1786.	1	1829.	1	1834.	1
1806.	1	1836.	1	1844.	1
1807.	2	1848.	1	Total	7
1815.	1	1850.	1		
	9	Total	17		

The same "Chronological Table" contains the following entries:—

"1760, December 1, Meteorological Phenomena."
"1815, February 5, Meteorological Phenomena."

I have not been able to ascertain what these phenomena were; but it is not improbable that they were auroral displays. The aurora of the 4th February, 1872, was described in some of the local newspapers as "*un phénomène météorologique*;" and we know that 1760 and 1816 were years of maximum auroral frequency. If, then, it be ascertained that the "meteorological phenomena" observed at Mauritius in 1760 and 1815 were auroræ, we shall have further evidence in favour of the theory of increased activity of the magnetical and meteorological elements in the maxima sun-spot years.

Baron Grant, in his 'History of Mauritius' (p. 194), regrets the destruction of the woods near Port Louis, because, he says, the town was thereby "exposed to the violence of the winds, as well as to the heat of the sun;" and in a footnote it is remarked, "these inconveniences, however, are fully counterbalanced, if it be true that *the cessation of hurricanes since* 1789 has been caused by the great diminution of the woods."

As the 'History' was published in or soon after 1801, it would appear that during the twelve years (1789 to 1801) no hurricane occurred in the island.

Now since, according to the Tables of sun-spot frequency, the years 1788 and 1804 were maxima years, and the intervening minimum occurred in 1798, the theory would lead us to expect a comparative cessation of hurricanes during the period mentioned.

If time permitted I would adduce similar evidence respecting the hurricanes of Bourbon (Réunion) and other parts of the world.

The hurricanes of the Indian Ocean are well known to be attended with torrential rains. So much is this the case, that the popular belief at Mauritius is that cyclones are the cause of our rains. Heavy rains over extensive areas are certainly concomitant with cyclones in the Indian Ocean. It was therefore determined to examine whether there was also a rainfall periodicity. As far as the Mauritius observations went, the case was clear; but it was desirable to extend the investigation to other localities. The Queensland and South-Australian observations gave similar results; and as Adelaide is far beyond the limits of tropical cyclones, it was surmised that there might be a rainfall periodicity generally. The Cape of Good Hope observations were afterwards found to support this view. The rainfalls of England and the Continent of Europe were next examined, and also found to be in accordance with the hypothesis.

It would occupy much more time than I can at present spare to enter fully into this question of rainfall periodicity. With the help of researches on the same subject by Mr. Lockyer, Mr. Symons, and Dr. Jelinek, of Vienna, I have now examined ninety-three tables of the rainfall for various parts of the world; and I find that, with few exceptions, more rain has fallen in the maxima than in the minima sun-spot years. I beg to append a Table showing the general results for the different quarters of the globe. It will be seen that, as far as the investigation has gone, Europe, Africa, America, and Australia give very favourable results. Asia is represented by only three stations, one of which is Jerusalem, where the excess of rain in one minimum period exceeds the excess in the maxima periods for two stations in India. France is the only European country (the rainfall of which has been examined) that gives an unfavourable return; but it must be remarked that we have as yet got only five stations in that country, most of which are inland, and that they may not fairly represent the whole country.

By taking the longest possible series of observations for several stations spread over the globe, a periodicity comes out; and there is, I think, very strong evidence that rainfall is subject to a secular variation, corresponding with the sun-spot variation.

Having given the facts, as far as I have been enabled to do so, I abstain from making any theoretical remarks, beyond saying that if cyclone and rainfall periodicities be fully established, a similar (direct) temperature periodicity should also exist, and that sudden variations of solar heat and radiation may, by disturbing terrestrial magnetism, be the cause of an increase of auroræ and magnetic storms when sun-spots are most numerous.

Catalogue of Cyclones experienced in the Indian Ocean, between the Equator and 34° S. Lat., from January 1st, 1847, to May 31st, 1873.

Date.	Locality. Lat. S.	Locality. Long. E.	Maximum force of wind.	Lowest reading of barometer.	Vessels by which experienced.	Remarks.
1847.	°	°		in.		
Jan. 1 and 2	24	59	12	......	Thomas Blyth, &c.	Vessels dismasted and lost.
Jan. 25 to 31	16 to 22	66 to 54	12	......	Charles Heddle, Comet, &c.	Vessels dismasted.
Feb. 6 to 9	17 „ 26	64 „ 54	12	27·15	Jacques Cantin, Lutin, Earl Grey, &c.	Bourbon suffered much; vessels dismasted, &c.
May 19	26	56	12	......	Echo	Dismasted.
Nov. 25 to Dec. 7	12 „ 24	76 „ 65	12	29·00	Anais, Mary Ann, &c.	Vessels dismasted.
						(Total, 5.)
1848.						
Jan. 10 to 22	9 to 12	84 to 72	12	27·50	Sir Howard Douglas, Wellesley, &c.	Vessels dismasted.
Jan. 19	20 „ 30	56 „ 45	11	29·00	Nautilus, &c.	Bourbon suffered.
Jan. 23 to 31	10 „ 28	94 „ 71	12	......	Bright Planet, &c.	Vessels dismasted.
Mar. 1 to 8	8 „ 26	85 „ 55	{12 12}	28·30	{Japan, Columbine, Boyne, Salaques, &c. (*two hurricanes*)}	'Dhur' foundered; vessels dismasted.
Mar. 14	24 „ 26	60 „ 57	12	28·60	Mercury, Vulcan, &c.	Vessels disabled.
Apr. 20 to 24	9 „ 14	86 „ 72	12	28·20	H.M.S. Jumna, Pemberton, &c.	Vessels dismasted, &c.
Nov. 10 to 13	0 „ 14	85 „ 83	11	......	Eucles, Alibi, &c.	Vessels damaged.
						(Total, 8.)
1849.						
Jan. 7 and 8	15	54	11	......	Lady Emma	Damaged.
Jan. 25 to 31	11 to 21	85 to 70	9	......	Claudine.	
Feb. 1 to 4	12 „ 23	80 „ 69	12	......	Delta, Peri, Eclipse, &c.	Vessels dismasted.
Mar. 12 to 15	13 „ 16	73 „ 71	10	......	Briton's Queen.	
Mar. 12	31	78 „ 60	9	29·69	Collingwood, Malabar, &c.	
Apr. 11 and 12	14 „ 22	70 „ 60	12	......	St. Peter, &c.	Houses blown down at Rodriguez.
May 29 and 30	8 „ 12	62 „ 59	10	......	Briton's Queen.	
Nov. 25 to 30	6 „ 16	85 „ 70	10	......	Futtah Salam.	
Dec. 9 to 11	26 „ 31	60 „ 55	11	......	Doris, Minstrel Boy, &c.	Vessels damaged.
Dec. 10 to 15	2 „ 14	84 „ 76	12	29·45	Apprentice, Elizabeth, &c.	Vessels damaged.
						(Total, 10.)
1850.						
Jan. 14	29	50	12	......	Henry Tanner, &c.	Vessels disabled.
Jan. 22 to 25	7 to 9	90 to 86	11	29·25	Morgiana.	
Feb. 7 to 9	19 „ 30	80 „ 75	12	28·45	Dispatch	Dismasted.

Feb. 27 to Mar. 4	17 to 24	66 to 54	12	28·80	Briton's Queen, &c.	Bourbon suffered much; vessels dismasted.
Mar. 3 to 10	14 „ 22	83 „ 73	11	......	Collingwood.	
Mar. 20 to 26	17 „ 22	70 „ 58	12	......	Columbus, Madura, &c.	Vessels dismasted.
May 28	28 „ 33	48 „ 43	11	29·20	Morgiana, Elizabeth Brown, &c.	
Dec. 12 to 14	30	60 „ 56	10	......	Collingwood, Tomatin, &c.	
						(Total, 8.)
1851.						
Feb. 27 to Mar. 2	25	79	11	......	Flying Dutchman	Damaged.
Mar. 18 to 25	14 to 25	75 to 64	12	27·20	Lord Nelson, Trafalgar, &c.	Vessels dismasted and abandoned.
Mar. 24 to 31	12 „ 22	70 „ 50	12	28·20	Josephine Loizeau, Louis, &c.	Part of Tamatave swept away; vessels dismasted.
Apr. 18	21	72	10	......	Will Watch.	
Nov. 5 to 17	6 „ 16	90 „ 75	12	28·24	Laidmans, Macedon, &c.	Vessels dismasted, &c.
Dec. 3 to 11	8 „ 12	98 „ 95	11	......	Globe, Princess Victoria, &c.	
Dec. 22 to 27	13 „ 18	87 „ 82	12	28·50	Bengal, Equestrian, &c.	
						(Total, 7.)
1852.						
Jan. 6 to 13	12 to 29	79 to 49	12	28·00	Diadem, Ariel, &c.	Vessels dismasted, &c.
Jan. 19 to 26	14 „ 29	75 „ 58	12	28·55	Equator, Belle Creole, &c.	Vessels dismasted, &c.
Mar. 30	20	113	10	......	Shah Allum.	
Apr. 6 to 10	5 „ 23	91 „ 68	12	......	Mayaram Dayaram, Rabinhaupt, &c.	Vessels dismasted, &c.
Apr. 18 and 19	29	45	10	......	Manoumbe.	
Nov. 3	10	87	12	29·60	Fazzel Carrim, Sir George Seymour, &c.	Vessels dismasted, &c.
Nov. 23 to 26	8 „ 10	88 „ 86	10	29·68	Hydroosee, Integrity, &c.	
Dec. 12 to 21	8 „ 18	60 „ 56	12	......	Deux Cousins, Dart, &c.	Damaged.
						(Total, 8.)
1853.						
Jan. 12 to 16	16 to 22	70 to 55	10	29·20	Ackbar, Lord Haddo, &c.	
Jan. 20 to 26	10 „ 24	85 „ 58	10	29·27	Futtah Sultan, John King, &c.	
Feb. 1 to 3	14 „ 17	86 „ 84	10	29·50	Asia.	
Feb. 9 to 12	28	46 „ 41	9	29·62	Eclipse.	
Feb. 18 to 19	17	100	10	29·50	Mary Harrison.	
Feb. 21	17 „ 22	62 „ 58	10	......	Alexander Auguste, Christabel, &c.	
Mar. 4 to 12	14 „ 34	76 „ 55	12	27·50	Johanna Catherina, Herald, &c.	Vessels damaged.
Apr. 21 to 30	70 „ 21	85 „ 60	11	29·57	Albert, Blue Bell, &c.	
						(Total, 8.)
1854.						
Feb. 9 to 13	17 to 20	77 to 57	12	28·80	Harpooner, Harlequin, &c.	Vessels damaged.
Feb. 26 to 28	7 „ 23	79 „ 52	11	29·40	Amy, Christabel, &c.	
Mar. 2 to 6	13 „ 19	75 „ 69	12	28·10	S. S. Lady Jocelyn, &c.	Vessels dismasted.
Nov. 25	10 „ 25	76 „ 66	12	27·80	Sesostris, Thetis, &c.	Vessels dismasted.
						(Total, 4.)

Catalogue of Cyclones (*continued*).

Date.	Locality. Lat. S.	Locality. Long. E.	Maximum force of wind.	Lowest reading of barometer.	Vessels by which experienced.	Remarks.
1855.				in.		
Jan. 18 to 24	11° to 26°	78° to 72°	12	27·80	Eleanor, Superb, &c.	Vessels dismasted, &c.
Jan. 21 to 25	14 „ 28	65 „ 56	12	27·80	Rosalie, Jupiter, &c.	Vessels dismasted, &c.
Mar. 22 to 26	16 „ 18	72 „ 61	10	29·18	Mayaram Dayaram.	
May 1 to 11	9 „ 20	81 „ 68	12	27·50	Watel Stroom, Parland, &c.	Vessels dismasted, &c.
Nov. 22 to 30	6 „ 14	90 „ 77	10	29·61	Cœur de Lion, Defiance, &c.	
						(Total, 5.)
1856.						
Feb. 4 to 6	24 to 32	60 to 57	10	29·52	Arab, John Edward, &c.	
Mar. 21 to 31	19 „ 24	70 „ 59	9	......	Sultan, Ajax, &c.	
Apr. 2 to 9	18 „ 28	63 „ 51	12	28·20	Annie, Estafette, &c.	Vessels disabled.
Nov. 7 to 11	5 „ 11	89 „ 82	10	......	Her Majesty, St. Michael, &c.	
						(Total, 4.)
1857.						
Jan. 27 to 30	17 to 20	69 to 56	12	29·08	Damblat, Avery, &c.	Vessels damaged.
Feb. 13 to 17	13 „ 20	72 „ 67	10	29·73	Aga Bahkur, S. Tynemouth, &c.	
Dec. 3 to 7	16 „ 24	62 „ 56	12	28·80	Rose, Governor, &c.	Vessels dismasted.
Dec. 27 to 31	10 „ 17	85 „ 81	11	29·15	Adelaide, Vesta, &c.	Vessels dismasted.
						(Total, 4.)
1858.						
Jan. 12 to 19	10 to 27	60 to 48	12	......	Trois Frères, Ida, Soubadhar, &c.	Bourbon suffered severely; vessels dismasted.
Feb. 24 to 28	20 „ 27	70 „ 55	10	29·55	Agatha, Tuscan, Black Eagle, &c.	
Mar. 6 to 18	14 „ 24	78 „ 60	12	28·30	Gwalior, S. Jason, &c.	Vessels dismasted, &c.
Mar. 6	15	53	12	28·90	Impératrice Eugénie	Dismasted.
Apr. 2 to 5	6 „ 10	87 „ 81	10	29·65	Twilight, Maréchal Pelissier, &c.	
Apr. 18 to 20	6 „ 10	94	11	......	Barretto	Damaged.
May 11 and 12	31	33	9	......	Rajah	Damaged.
Nov. 2 to 11	10 „ 26	85 „ 56	9	......	Crawfords, Astræa, Royal William, &c.	
Dec. 8 to 16	12 „ 23	97 „ 91	10	29·83	Allies, Nimrod, &c.	
						(Total, 9.)
1859.						
Jan. 1 and 2	17 to 19	86 to 60	10	......	Lady Valliant, Barnham, &c.	
Jan. 24 to 29	14 „ 33	79 „ 54	9	29·60	Rydal, Formosa, Thames, &c.	
Feb. 16 to 21	30 „ 33	58 „ 55	10	29·78	Japan.	
Mar. 5 to 11	16 „ 25	72 „ 59	12	29·0	Narwhal, Magi, Isis, &c.	Vessels damaged.

Mar. 16 to 20 ...	4 to 24	88 to 76	12	29·50	Cataraqui, Adelaide, &c.	Vessels dismasted.
Apr. 4 to 6	31 „ 29	56 „ 54	9	......	Symmetry, Holyrood, &c.	
Apr. 5 and 6	13 „ 16	91 „ 92	9	......	Annie Buckman, City of Palaces, &c.	
Apr. 16 to 18 ...	9 „ 15	89 „ 85	10	......	Alma, Mayaram Dayaram, &c.	
Apr. 19 to 22 ...	31 „ 36	46 „ 28	10	......	Rothay, Valentine, &c.	
Apr. 22	6	84	11	......	Storm Queen	Lost topmasts, &c.
May 30 and 31 ..	32 „ 34	33 „ 18	10	29·50	Espérance, Tamarac, Rheine, &c.	
June 1 to 5	4 „ 18	84 „ 71	11	......	Sultan, Hants, &c.	Vessels damaged.
Nov. 16 to 19 ...	0 „ 3	85 „ 82	10	......	Ashburton, Caucasian, &c.	
Dec. 2 to 6.	9 „ 15	85 „ 73	9	......	Lancaster, George Akle, &c.	
Dec. 9 to 16	9 „ 29	55 „ 40	12	28·40	Pieter, Thomas Pope, &c.	Vessels dismasted.
						(Total, 15.)
1860.						
Jan. 9 to 16	11 to 30	70 to 59	12	28·82	Anglo-Saxon, Eleanor, Ibis, &c.	Vessels dismasted, &c. [dismasted.
Jan. 17 to 22......	15 „ 22	75 „ 59	12	28·31	Yarra, Uriel, Lawrence, &c.	Portuguese brig of war foundered; vessels
Jan. 25 to 28......	16 „ 24	57 „ 55	12	29·25	Atieth Rohaman, Gironde, &c...	Vessels damaged.
Feb. 11 to 16......	19 „ 30	54 „ 52	11	29·54	Lord of the Isles, Good Hope, &c.	Vessels damaged.
Feb. 22 to 27......	15 „ 24	60 „ 52	12	28·00	Phœnix, Chêne, Colbert, &c......	Vessels dismasted and foundered.
Feb. 22 to 25......	14 „ 19	75 „ 70	11	29·54	Martha, Joseph Bushby, &c.	Vessels damaged.
Feb. 28 and 29 ...	12	103	12	. ...	Der Sud	Dismasted.
Mar. 2 and 3......	9 „ 12	83 „ 80	10	29·62	Adelaide, Eunomia, &c.	
Mar. 18 to 27 ...	14 „ 35	68 „ 57	12	28·20	Jeannie Dove, S. Powerful, &c.	Vessels dismasted.
Apr. 26 and 27 ...	11 „ 14	80 „ 78	11	......	Hotspur, Edmundsbury, &c.	
May 27 to 31......	8 „ 15	84 „ 79	11	.. . .	Icene, Mary Sparks, &c.	
May 28 to 30......	26 „ 29	60 „ 52	12	28·95	Damietta, Ceres, &c.	Dismasted, &c.
Dec. 5 to 8	9 „ 14	82 „ 75	10	......	Maggie Miller.	
						(Total, 13.)
1861.						
Jan. 18 to 20......	16 to 20	65 to 58	11	29·30	Kirkland, Sir John Moore, &c.	
Feb. 1 to 4.........	20 „ 23	72 „ 69	12	28·60	Mascate, Thames, &c.	'Mascate' dismasted.
Feb. 4 to 16	10 „ 20	80 „ 72	12	28·90	Meteor, Georges and Juillette, &c.	Vessels dismasted and foundered.
Feb. 9 to 20	12 „ 28	64 „ 56	12	28·30	Wild Wave, Carn Tual, Cuban, &c.	Vessels dismasted and foundered; Mauritius suffered.
Mar. 1 to 8	10 „ 38	68 „ 49	12	28·50	Alliance, Rubens, Norman, &c.	Vessels dismasted, &c.; Mauritius suffered.
Mar. 10 to 16 ...	10 „ 15	105 „ 92	11	......	Ebba Brahe, Elizabeth, &c.	
Mar. 28............	33 „ 36	58 „ 53	10	29·68	Flibberty, Aurore, &c.	
Apr. 4 to 9	12 „ 30	80 „ 59	10	......	Emmanuel, Marian, &c.	
Apr. 12 to 19......	16 „ 24	76 „ 50	9	......	Smyrna, Emily Smith, &c.	
Nov. 1 to 6	2 „ 14	91 „ 74	9	29·55	City of Carlisle, Regina, &c.	
Dec. 18 to 31......	11 „ 24	86 „ 68	12	29·37	Formosa, Nile, Galatea, &c.	Vessels dismasted.
						(Total, 11.)

Catalogue of Cyclones (*continued*).

Date.	Locality. Lat. S.	Locality. Long. E.	Maximum force of wind.	Lowest reading of barometer.	Vessels by which experienced.	Remarks.
1862.	°	°		in.		
Jan. 2 to 8	14 to 20	80 to 78	12	......	Leonie, Martaban, &c.	Vessels dismasted.
Jan. 16 to 19	24 " 30	60 " 46	10	29·20	Goa, Matchless, &c.	
Jan. 21 to 23	11 " 19	60 " 56	9	......	Hyderee, Shah Allum, &c.	
Jan. 27 to 31	8 " 30	72 " 57	9	......	Sphinx, Ellen, Belsize, &c.	
Feb. 20 to 28	8 " 17	110 " 60	12	29·10	Nimrod, Cantero, Finella, &c.	Vessels dismasted.
Mar. 5 to 12	18 " 30	58 " 32	10	......	H.M.S. Gorgon, Thomas Blyth, &c.	
Mar. 20 to 27	10 " 20	80 " 73	12	29·20	Jean Louis, Thames Clemence, &c.	
Oct. 10 to 12	4 " 9	60 " 55	11	29·30	H.M.S. Orestes, Nepaul, &c.	Inundation at Seychelles.
Nov. 25 to Dec. 4	10 " 29	86 " 70	11	29·50	Dart, Phantom, Echo, &c.	Vessels damaged.
Dec. 17 to 22	0 " 12	83 " 80	12	29·50	Egmont, Toftcombs, &c.	(Total, 10.)
1863.						
Jan. 10 to 15	12 to 24	61 to 56	11	29·15	Marie Anais, Royal Arthur, &c.	Vessels damaged; houses unroofed at Mauritius.
Feb. 1 to 6	14 " 31	62 " 54	12	28·60	Hadleys, Clifford, &c.	Great damage at Bourbon; vessels dismasted, &c.
Feb. 9 to 13	8 " 20	78 " 55	10	......	Ibis, Success, Express, &c.	
Feb. 18 to 24	15 " 33	70 " 50	12	28·80	Deane, John Fairbairn, &c.	Dismasted.
Mar. 11 to 20	25 " 28	73 " 59	9	......	Hanna Nicholson, Lézard, &c.	
Apr. 15 to 23	8 " 18	99 " 75	12	28·28	Eva Johanna, Alaya, &c.	Vessels dismasted, &c.
May 12 to 21	6 " 16	90 " 77	12	27·30	Earl Dalhousie, James Russel, &c.	Vessels dismasted and foundered.
Nov. 25 to 27	6 " 12	89 " 84	12	28·34	Raritan, Dominion, &c.	Vessels dismasted.
Dec. 6 to 8	17 " 24	63 " 57	11	......	Espoir, Rose, Myrtle, &c.	'Espoir' dismasted. (Total, 9.)
1864.						
Jan. 9 to 20	10 to 25	83 to 62	11	29·05	Gyptis, Helene, Jessamine, &c.	
Jan. 29	31	48	10	29·74	S.S. Amberwitch.	
Feb. 24 to Mar. 6	12 " 28	78 " 56	12	28·40	Prince of Wales, Hero of the Nile, &c.	Vessels damaged.
Apr. 13 to 19	8 " 13	82 " 73	11	29·50	Azzopardi, Inconstant, &c.	
Apr. 22 to 30	14 " 31	70 " 65	12	......	Bernardin de St. Pierre, Canton, &c.	'St. Pierre' dismasted. (Total, 5.)
1865.						
Jan. 10 to 13	14 to 18	56 to 50	10	29·70	Lynx, Anna Heloise, &c.	
Jan. 21 and 22	32	59	10	29·50	Good Hope.	
Feb. 20 to 24	12 " 20	65 " 56	11	29·36	S. S. Norna, Jehangeer, &c.	
Feb. 14 to 24	12 " 24	86 " 68	12	28·90	Cambrian, Glenlee, &c.	'Cambrian' dismasted.

Mar. 20 to 26 ...	12 to 20	87 to 80	12	27·07	Sultana, Beau Monde, &c.	Vessels dismasted.
Apr. 14 to 17......	9 „ 22	80 „ 73	11	29 65	Garibaldi, Johanna Maria, &c.	
Dec. 6 to 11	10 „ 20	60 „ 58	10	......	Romp, Vistula, &c.	
						(Total, 7.)
1866.						
Jan. 6 to 12	6 to 15	74 to 67	11	29·72	Phare, Rio, &c.	
Feb. 1 to 4.........	18 „ 20	77 „ 67	10	29·53	Duiveland, Jean Baptiste, &c.	
Mar. 1 to 7	11 „ 20	88 „ 79	12	29·10	Spectator, Agnes, &c.	'Spectator' dismasted.
Mar. 30 and 31...	14 „ 16	81 „ 79	10	......	Anglo-Saxon.	
Apr. 6 to 17	0 „ 20	80 „ 88	11	......	St. Hilda, Thaletta, &c.	
Apr. 15 to 26......	16 „ 27	62 „ 53	11	......	Jessie Byrne, Faithful, &c.	
Nov. 13 and 14 ...	13	75 „ 72	11	29·38	Geologist, City of London, &c.	
Nov. 30	8	88	9	29·67	Hamilton.	
						(Total, 8.)
1867.						
Jan. 15 to 21......	10 to 22	72 to 66	11	29·41	Rio, Osiris, Star of India, &c.	
Feb. 1 and 2	15	81	11	29·46	Montrose	Cut away topmasts.
Feb. 12 to 20......	12 „ 25	75 „ 58	11	29·55	Queensland, Francis Henty, &c.	
Apr. 10 to 14......	20	61	10	29·65	Saxon, Silver Star, &c.	
May 22 to 28	13 „ 22	79 „ 61	11	......	Royal Albert, Victoria Bridge, &c.	'Royal Albert' cut away mizzen mast.
Dec. 15 to 18	20 „ 25	59 „ 58	10	29·56	Mauritius, Crochragnes, &c.	
						(Total, 6.)
1868.						
Jan. 2 to 5.........	9 to 28	80 to 56	11	28·90	Arabia, Cattofield, &c.	
Jan. 14 to 25......	14 „ 20	70 „ 49	12	28·80	West Indian, Albion, &c.	Vessels damaged, &c.
Feb. 1 to 10	18 „ 30	74 „ 50	12	27 60	Sea Star, St. Anne, &c.	Vessels damaged, &c.
Mar. 7 to 15	10 „ 28	80 „ 55	12	27·20	Pionnier, Sarah, Carn Tual, &c.	Great damage at Mauritius; vessels dismasted, &c.
Apr. 19 to 23 ...	8 „ 32	78 „ 51	11	29·40	Penelope, Emma, &c.	
May 3 to 8	14 „ 18	61 „ 54	10	29·68	Caprice, Mozambique, &c.	
Nov. 9 to 14	8 „ 25	85 „ 60	10	29·53	Pierre, Emile Irma, &c.	
						(Total, 7.)
1869.						
Jan. 19 to 24......	22 to 26	59 to 57	9	29·88	Amanda.	
Feb. 7 to 13	20 „ 28	57 „ 46	11	29·44	Sea Breeze.	
Feb. 17 and 18 ...	23 „ 25	70 „ 67	12	28·55	Iron King	On beam ends; had to cut away topmasts.
Feb. 24	21	85	10	29·43	Elizabeth.	
Mar. 24 and 25...	19 „ 20	59 „ 58	9	......	Sir Hugh Rose.	
Apr. 8 and 9	14 „ 18	75 „ 73	12	28·50	Glenroy, Suzanne, &c.	Vessels dismasted.
May 7 and 8......	19	64	10	29·76	St. Philbert.	
Nov. 16 to 22 ...	7 „ 16	89 „ 85	10	29·52	Hindostan, Morning Star, &c.	
Dec. 17 to 19......	23	79	12	28·36	Prospero	Dismasted. (Total, 9.)

Catalogue of Cyclones (*continued*).

Date.	Locality. Lat. S.	Locality. Long. E.	Maximum force of wind.	Lowest reading of barometer.	Vessels by which experienced.	Remarks.
1870.	°	°		in.		
Jan. 6	2	87	10	......	Inverdruie.	
Jan. 30 and 31	14	57	11	......	Vistula	Damaged.
Feb. 12 and 13	31	57	10	......	Royal Berkshire, Perigny, &c.	
Feb. 19	20	59	9	29·50		
Mar. 9 to 11	20 to 27	61 to 58	10	......	Loch Awe.	
Apr. 3 to 5	20 „ 22	69 „ 58	......	......	Denis Affre, Crown, &c.	
Apr. 14 to 20	9 „ 16	104	12	......	Melrose, Ocean Bell, &c.	Vessels dismasted, &c.
Apr. 12 to 20	12 „ 19	77 „ 70	12	......	Zealandia, Glenlora, &c.	Vessels dismasted, &c.
May 8 to 11	0 „ 3	95 „ 90	10	......	Nimrod, Rutlandshire, &c.	
June 2	0	92	10	......	St. Vincent de Paul.	
Nov. 12	8	85	9	......	Northumberland.	
Nov. 27 to 30	28 „ 29	62 „ 51	9	......	Astræa, Maréchal Pelissier, &c.	
						(Total, 12.)
1871.						
Jan. 2 to 11	17 to 30	60 to 57	12	28·94	Anne Marie, Glen Isla, &c.	Vessels dismasted and otherwise damaged.
Jan. 6 to 11	10 „ 24	88 „ 75	12	29·62	Latona, Tasso, &c.	Vessels dismasted and otherwise damaged.
Jan. 19 to 27	5 „ 25	90 „ 75	12	......	Alabama	Vessels dismasted and otherwise damaged.
Feb. 21 and 22	10	91 „ 89	10	......	Merchantman, Shand, &c.	
Apr. 21	21	85	10	......	Orissa.	
May 27 and 28	25	52 „ 50	9	......	Prospero.	
May 29	18	101	9	......	Corrido.	
May 30 and 31	15	120	9	......	Alexandrine.	
July 6 to 12	9 „ 14	103 „ 92	11	29·41	Nimroud.	
Nov. 5 to 8	9	97 „ 93	11	28·49	Amie	Damaged.
Nov. 28	27	47	10	......	Island Belle.	
						(Total, 11.)
1872.						
Jan. 28 to Feb. 4	19 to 31	53 to 31	12	28·40	Emily, Abbotsford, &c.	Vessels damaged.
Feb. 5 to 9	16 „ 27	72 „ 64	11	29·20	Elizabeth, Daphne, &c.	
Feb. 8 to 20	10 „ 30	84 „ 50	12	27·72	W. Fairbairn, Staffordshire, &c.	Vessels dismasted, &c.
Feb. 22 and 23	12	101	12	29·29	Ship *C. J.*	Dismasted.
Mar. 13	....	....	12	......	....	At Tamatave and Mahanero (Madagascar); vessels lost.
Mar. 15 to 21	20 „ 24	82 „ 65	11	29·66	Wodonga.	
Apr. 2 to 5	23	61	9	......	Spirit of the South.	

Apr. 15	....	....	12	......	....	At Zanzibar.
May 4 to 6	18 to 21	70	11	29·40	Dovercourt, Octavia, &c.	
May 6..............	28	82	11	......	Bayard...	"Blowing a hurricane."
May 19 and 20 ...	18 „ 24	68 to 65	10	......	Kursovie, Hudiksvall, &c.	
July 12 to 14......	0	95	11	29·80	Impulse	"Perfect hurricane."
Oct. 31 to Nov. 1	18 „ 20	67 „ 62	12	......	Agricola, Fathe Salem, &c.	Hurricane passed over Rodriguez. (Total, 13.)
1873.						
Jan. 2 to 13	7 to 25	70 to 50	12	......	Adeline, Brisk, &c.	Great damage at Bourbon; vessels foundered and dismasted.
Jan. 11	31	48	11	28·70	Sassello, Marini, &c.	Vessels damaged.
Jan. 19 to 26......	12 „ 30	60 „ 53	10	29·80	Tapageur, Almena, &c.	
Feb. 2 to 10	10 „ 26	74 „ 60	12	27·95	Falcon, Riversdale, &c.	Crops at Rodriguez destroyed; vessels dismasted and foundered.
Feb. 18 to 26......	18 „ 30	60 „ 53	11	......	Rio, Patna, &c.	
Mar. 9 to 14	16 „ 24	74 „ 60	12	28·70	Prince Alfred, Chalmers, &c.	Terrific hurricane at Rodriguez; vessels dismasted.
Mar. 18 to 22 ...	12 „ 22	86 „ 77	11	......	Dunmore, Red Riding Hood, &c.	
Apr. 4 to 10	17 „ 21	65 „ 59	10	29·84	Abington, Margaretha, &c.	
Apr. 17	16	111	12	......	Umvoti.	
May 4 to 7	27 „ 30	63 „ 60	10	29·60	Nerée.	
May 24 and 25 ...	30	58	11	......	Chauteaubriand.	
May 28	10	82	11	......	Blanche.	(Total, 12.)

REMARKS.

The latitudes and longitudes given under the heading "Locality" show approximately where the cyclones began and ended according to the log-books, and not the actual limits.

The numbers indicating the maximum force of the wind (9, 10, 11, 12) denote respectively, Strong Gale, Whole Gale, Storm, and Hurricane; and it may be that a gale (9) was really part of a hurricane (12), the vessels which experienced it being considerably distant from the centre.

The lowest observed readings of the barometer do not always show the actual lowest atmospheric pressure in the cyclones, but the lowest pressure noted in the log-books. Barometers are not unfrequently injured or broken during hurricanes, and sometimes no barometer at all is on board; hence there are blanks in the column of "lowest barometer." It must be remarked also that the observed (not the corrected) readings are given.

Table showing the Rainfall over the Globe during Maxima and Minima Sun-spot periods of three years each, and the Excesses or Defects in the Maxima periods.

Quarters of the globe.	Countries, &c.	Number of stations.	Number of maxima and minima periods of three years each.	Years of observation, from	to	Rainfall in maxima periods.	Rainfall in minima periods.	Total excess (+) or defect (−).	Mean annual excess or defect.
						in.	in.	in.	in.
Europe	England	2	14	1815.	1869.	625·77	574·93	+ 50·84	+ 2·42
	Scotland	19	98	1815.	1872.	5689·25	5172·58	+ 516·67	+ 3·51
	Norway	1	4	1839.	1863.	137·56	116·95	+ 20·61	+ 3·43
	Russia	2	12	1832.	1870.	289·37	248·07	+ 41·30	+ 2·29
	Belgium	1	6	1833.	1861.	268·62	245·02	+ 23·60	+ 2·62
	France	5	28	1832.	1861.	1124·60	1290·10	− 165·50	− 3·94
	Prussia	25	74	1832.	1870.	2737·25	2377·46	+ 359 79	+ 3·24
	Austria	5	28	1832.	1870.	1310·55	1271·77	+ 38·78	+ 0·92
	Italy	2	10	1832.	1870.	388·78	380·39	+ 8·39	+ 0·54
	Switzerland	2	12	1832.	1861.	809·20	729·90	+ 79·30	+ 4·41
Asia	India	2	6	1843.	1871.	581·97	529·87	+ 52 10	+ 5·78
	Palestine	1	2	1847.	1857.	175·80	259·20	− 83·40	−27·80
Africa	Algiers	1	4	1843.	1861.	197·10	198·10	− 1·00	− 0·17
	Oran	1	4	1843.	1861.	101·70	133·80	− 32·10	− 5·35
	Constantine	1	2	1855.	1861.	69·40	56·20	+ 13·20	+ 4·40
	Cape of Good Hope	1	4	1842.	1870.	172·50	133·70	+ 38·80	+ 6·47
	Natal	1	2	1858.	1867.	81·41	91·85	− 10·44	− 3·48
	Mauritius	1	4	1853.	1872.	306·72	254·06	+ 52·66	+ 8·78
America	Canada	1	2	1854.	1869.	102·20	106·90	− 4·70	− 1·57
	United States	3	8	1832.	1849.	505·10	450·90	+ 54·20	+ 4·52
	Do. do.	11*	2	1854.	1859.	506·06	359·77	+ 146·29	+13·30
	New Granada	1	2	1836.	1845.	301·80	223·70	+ 78·10	+26·03
	Demerara	1	2	1846.	1856.	331·46	275·94	+ 55·52	+18·51
	Barbadoes	1	4	1843.	1861.	344 90	334·40	+ 10·50	+ 1·75
Australia	Queensland	1	2	1860.	1871.	124·51	98·28	+ 26·23	+ 8·74
	South Australia	1	2	1839.	1860.	72·79	61·61	+ 11·18	+ 3·73
	Sums	93	338			17356·37	15975·45	+1380·92	+83·08

* For these eleven stations the fall in 1856 is compared with that in 1859.

Fifth Report of the Committee appointed to investigate the Structure of Carboniferous-Limestone Corals. Drawn up by JAMES THOMSON, *Secretary. The Committee consists of* Professor HARKNESS, *F.R.S.*, JAMES THOMSON, *F.G.S.*, DR. DUNCAN, *F.R.S.*, *and* THOMAS DAVIDSON, *F.R.S.*

DURING the past year the Committee have continued their investigations with increased interest. Indeed the longer they continue their investigations in this branch of palæontology, the more they are impressed with its importance; and now that they can reproduce in facsimile the internal structures of fossil corals, they hope that the British Association will be convinced of the propriety of continuing these researches.

Within the period embraced by the Report upwards of 200 specimens have been sliced; these are from a locality in Fifeshire, which had escaped our notice. Many of these specimens, in addition to confirming the discovery of new forms (noticed in a previous Report), exhibit structural characteristics that warrant us in determining two (if not three) new genera.

There are others figured this year in Plates*, upon which we at present hesitate to decide. They require careful comparison before we can feel confident of the group in which they must be classed.

In the Report of last year it was stated that the gradations of varieties are in some cases so constant, and the species pass so imperceptibly into each other, that we are induced to infer that there has been an inherent tendency in the polyp to vary independent of, but modified by, the conditions of its surroundings. It was also stated that it was our intention to figure these variations, so as to enable us to see what are the essential characteristics that distinguish the species. We have accordingly prepared six Plates and figured 284 forms, showing in each case the internal structure. The external aspect is also represented when necessary.

We have deferred to another occasion our treatment of such forms as *Beaumontia*, *Alveolites*, *Favosites*, &c. Some palæontologists have doubts as to whether several genera should be retained among the Rugose Corals, so that we are the more induced to delay dealing with several forms belonging to this group; and we feel convinced that our future researches will bring to light specimens simpler in organization, but presenting new facts which may cause considerable alteration in the classification of this group. It is better, therefore, to wait until these distinctive characteristics are clearly brought out. We have, however, given in (what we provisionally call) Plate I. some forms which are closely allied to the above.

Plate I. contains twenty-three figures of the genus *Amplexus*. Ten of these forms have not been recorded before, whilst others are now for the first time recorded as occurring in British strata. These figures represent the development of coralline life, passing from the simplest forms to the more complex structures of the genus, which passes by imperceptible gradations into the genus *Zaphrentis*. Prof. De Koninck finds a similar transition in the Mountain-Limestone Corals of Belgium belonging to this genus (Recherches sur les Animaux Fossiles Belgique, prem. part. p. 81).

Figs. 22, 23, 25, 26, 28, 30, 31, and 32 have not been represented before, and their structural characteristics are distinctly different from any of the forms that have hitherto been described.

Plate II. contains sixty-six figures; twenty-one of these are varieties of

* The Plates referred to in this Report will be published by Mr. Thomson.

the genus *Zaphrentis*. Figs. 8 and 27 represent a new genus; they are from Fifeshire. Fig. 8 may possibly be determined as a distinct species. Fig. 7 belongs to the same group, and will form another species. These forms are readily distinguished from all other corals belonging to this period by the granular costæ.

Fig. 26 is closely allied to the genus *Lophophyllum*; but it differs in structural characteristics from the species described by Prof. M'Coy in the 'Ann. of Nat. Hist.,' 2nd series, vol. vii. p. 167, and in 'Brit. Palæont. Fossils,' p. 90, 1851.

Figs. 23, 40, 42, and 43 are very much alike in external aspects; and it is only from transverse sections that they can be determined as belonging to distinct species. The other forms figured in this Plate require careful comparison before we can determine to what species or even genera they belong.

Plate III. contains thirty-three figures, representing twelve varieties of the genus *Zaphrentis*.

Fig. 1 is *Zaphrentis Enniskilleni*; and figs. 2, 3, 3 A, 3 B, and 3 C represent the same coral cut into five different sections, to show the structural characteristics in the different stages of development.

Fig. 5 is *Zaphrentis Edwardsiana* of De Koninck. Fig. 14 is *Zaphrentis Guerangeri*, E. & H.

The internal structures of the other forms upon this Plate have not been figured before, and therefore we deem it prudent to say nothing about them until they have been more carefully and closely examined. At some other time we may return to them.

Plate IV. represents forty-three species. Figs. 1 to 6 represent varieties of *Amplexus* and *Zaphrentis*. Figs. 3 and 4 have a striking resemblance externally, but in internal structure they represent two distinct genera, viz. *Amplexus* and *Zaphrentis*; and this fact confirms the statement made last year, that we cannot rely upon external aspects for purposes of specific identification.

Figs. 14, 15, and 26 belong to the genus *Lophophyllum*. These three forms have characteristics sufficient to warrant us in classifying them as distinct varieties.

Fig. 28 belongs to the same genus, but differs from the others in having two of the primary septa passing into nearly the centre of the calicular cavity, and terminating subreniformly at the inner extremity.

Fig. 21 C is *Heterophyllia Lyellii*, nat. size. Fig. 21 is the same, magnified; 21 A is a transverse, and 21 B a longitudinal section of the same.

Fig. 36 is *Heterophyllia grandis*. This is the first time that this form has been recorded from Scotch strata. Fig. 36 A is a longitudinal section of the same, showing the internal structure. Figs. 36 B, 36 C, and 36 D are transverse sections, exhibiting structural characteristics at different stages of development.

Fig. 37 is a new species of the same genus.

Fig. 38 is *Heterophyllia angulata*, while figs. 38 A and 38 B represent the structures in longitudinal and transverse sections.

Figs. 39, 39 A, and 39 B have well-marked specific distinctions. They must represent forms which differ from the other species of this genus. The septal arrangement is quite distinctive. It is certainly a new species. We propose to name it *Heterophyllia Phillipsii*.

Fig. 40 represents the external aspects of *Heterophyllia mirabilis*, nat. size. This is the typical specimen that Dr. Duncan described in the 'Transactions of the Royal Society' (1867, p. 643). Fig. 40 B is the same, magnified. This species is distinguished from the other species by a series of

curved spines which are attached to the crown of the costæ. They are round, and attached to the costæ by a broad, expanded base. The "ball-and-socket" process alluded to by Dr. Duncan we have failed to discover. Fig. 40 C is a transverse section of the same, nat. size.

Figs. 7, 9, 10, 11, 13, 16, 17, 18, 23, 24, 25, 27, 29, 30, 32, 33, 34, and 35 exhibit structural characteristics hitherto unnoticed. Several of these forms may be seen in many of our museums and private collections named as *Cyathropsis* and *Zaphrentis*; but in structure they have no characteristics common to either of these genera.

Figs. 21, 38, 40, 41, 42, and 43 are typical specimens of *Heterophyllia*, described by Dr. Duncan in the 'Transactions of the Royal Society' for 1867.

Plate V. contains six varieties of genus *Clisiophyllum*.

Fig. 1 represents the external aspect of *Clisiophyllum Keyserlingi*. This species is distinguished by the lamellæ curving round, and ascending to the crown of the large conical boss that fills up the centre of the calicular cavity. Fig. 1 A is a transverse section of the same. Fig. 1 B exhibits a longitudinal section, with the columellarian line passing down the centre of the coral.

Figs. 3, 3 A, 3 B, and 3 C belong to the same species, and represent the structures from the earliest to the mature state of development in any normal specimen.

Fig. 6 is a transverse section of the largest specimen of the same that has come under our observation.

Figs. 2, 4, and 5 are closely allied species, if not varieties.

Figs. 9, 11, 12, and 13 are distinct species, and illustrate a previous observation, viz. that specific identification cannot rest on the mere number of the lamellæ filling up the columellarian space in the centre of the calice.

Fig. 12 A is 15 lines in diameter, and has twenty-seven lamellæ.

Fig. 11 is only 6 lines in diameter, and has thirty-seven lamellæ filling up and forming the conical boss in the centre of the calice.

Figs. 7, 8, and 10 are distinct genera. These forms, before being cut, were classified as genus *Clisiophyllum*; but the transverse sections present no characteristics in common with that genus. They belong to a genus quite distinct, and as yet unnamed.

Plate VI. contains representations of three species of *Lonsdallia*.

Fig. 1 represents a longitudinal section of *Lonsdallia rugosa*. Figs. 1 B and 1 C exhibit the young corallites in their different stages of development.

Fig. 2 is a transverse section of the same species. In this section we have delineated the growth from the ovular germ through the different stages of development to the mature coral. In one stage the embryo coral is seen passing from the interseptal locula; in another it is seen semicircular in outline, and just outside the epitheca. In some it is circular in outline, whilst others exhibit the full development of the septa. Fig. 2 A is the same species, enlarged six diameters.

Fig. 3 represents *Lonsdallia duplicata*.

Fig. 4 A is one of the corallites enlarged, with a young corallite attached to the epitheca, exhibiting the development of the primary septa, which, in the maturer forms, is seen to fill up the columellarian space.

It will thus be seen that we wish to avail ourselves of every fact, and to delineate the most delicate structures. To accomplish the latter, our peculiar process is well suited. We may thus assist the student and beginner in

identifying specimens; but we may also check the superficial and hasty generalization and classification of the more advanced.

In regard to the stratigraphical distribution and duration in time of these forms, we must meantime remain silent; but by-and-by these will be duly recorded.

Report of the Committee, consisting of Colonel LANE FOX, Dr. BEDDOE, Mr. FRANKS, Mr. FRANCIS GALTON, Mr. E. W. BRABROOK, Sir J. LUBBOCK, *Bart.*, Sir WALTER ELLIOT, Mr. CLEMENTS R. MARKHAM, *and* Mr. E. B. TYLOR, *appointed for the purpose of preparing and publishing brief forms of Instructions for Travellers, Ethnologists, and other Anthropological Observers. Drawn up by* Colonel A. H. LANE FOX.

SHORTLY after the last Meeting of the Association I received an intimation from the Geographical Society that two expeditions were about to start in search of Dr. Livingstone—the one under Lieut. W. J. Grandy, R.N., by the Congo river, and the other, under Lieut. Cameron, from the East Coast—and requesting that anthropological instructions might be furnished to those officers for their guidance. As not more than a week's notice was given me of the departure of these expeditions, and it appeared desirable that each party should be provided with printed instructions, I wrote at once to several members of the Committee, requesting them to send me a series of questions for the use of the travellers; and the following gentlemen having responded to my appeal without delay, I caused their contributions to be printed in a small volume having blank leaves for memorandums and answers to the questions, each of which was numbered; and a sufficient number were furnished to the officers commanding each expedition, who were requested to distribute them on the coast to Her Majesty's Consuls, officers of the Royal Navy, and others who might be in a position to use them, or to place them in the hands of other travellers who might set out on expeditions towards the interior from time to time.

The following Members of the Committee were contributors to this volume, viz. A. W. Franks, Esq., on General Anthropology; Prof. Rolleston, F.R.S., on Physical Anthropology; Dr. Beddoe, F.R.S., on Physical Anthropology; E. B. Tylor, F.R.S., on Religions, Mythology, and Customs; Colonel A. H. Lane Fox on the Use of Iron in Africa, and on Prehistoric Archæology.

I enclose a copy of these instructions for the information of the General Committee.

Although these instructions have been the means of carrying out to a great extent the wishes of the Council of the Association in appointing the Committee, and it was important that the opportunity afforded by the starting of these expeditions should not be lost, yet as the instructions were drawn up solely with a view to African exploration, and a certain amount of repetition was apparent in the volume, owing to the hurried manner in which it was drawn up and printed, so as to be in time for the travellers before starting, it did not appear to me to meet as fully as could be desired the intentions of the General Committee in placing a grant of £25 at our disposal, such grant having been intended for the information of travellers

in general rather than for the use of travellers in any one quarter of the globe. I have therefore defrayed the cost of printing at my own expense, and the amount has been made up to me by copies purchased by the Geographical Society, the Anthropological Institute, and by Mr. Franks. This volume, therefore, although issued under the auspices and with the approval of the Committee, will not be charged to the Association.

The Committee for drawing up "General Instructions for Travellers" met on the 21st of November, 1872, when the following resolutions were passed:—

1. That the work to be published by the Committee shall consist of numbered sections, each section being prefaced by a few lines of explanatory notes and followed by questions.

2. That the notes and questions shall be expressed as briefly as possible.

3. That the Secretary be requested to draw up the headings of about 100 sections, and submit them to the Committee at their next meeting.

4. That the Secretary be requested to draw up a specimen section or sections upon half margin, and circulate them amongst the Members of the Committee for their remarks previously to the next meeting of the Committee.

5. That the title of the work shall be "Notes and Queries on Anthropology for the use of Travellers and Residents in uncivilized lands."

6. That M. Broca's chromatic tables be adopted; and that Dr. Beddoe be requested to communicate with him for the purpose of ascertaining in what manner they can be most economically reproduced in this country.

Acting upon these resolutions I drew up a list of 100 sections, which, having been circulated amongst the members for their remarks, have been printed in their approved form and are herewith annexed, together with the names of some of the authors to whom the sections have been submitted for detailed questions. Two specimen sections have also been circulated, and have been approved by the Committee.

Owing to the large number of contributors there has been some delay in collecting the contributions of the several authors. The sections have, however, now been completed continuously up to No. XLII., and some of the later ones have also been received; these sections are now in manuscript ready for printing. The sections have been divided into three parts,—Part I. relating to the Constitution of Man, Part II. to Culture, and Part III. to Miscellaneous Questions relating to Anthropology. The List of Sections will form an index to the volume; and for convenience of reference the sections have been numbered in Roman figures, the questions in italics. Each section has been submitted to some writer who is known to have devoted his special attention to the subject referred to him, and, as far as possible, the best known authorities have been selected.

The cost of printing the part already in type amounts to £3; that of the MS. already in hand has been estimated at £10.

The probable cost of the whole work, including illustrations and the chromatic tables, will be about £50.

Viewing the importance of the contributions already received and the scientific status of the contributors, and considering that the work is exhaustive of its subject and calculated to suffice for the use of travellers for some time to come, I would suggest, on behalf of the Committee, that the grant of £25 voted at the last Meeting be renewed, and £25 added to complete the work. The volume may then be published without delay.

It may be estimated that the sale of copies will cover a portion of the expenses.

List of Sections into which the Notes and Queries on Anthropology are divided, with a Summary of the Subjects included in each Section.

Part I.—CONSTITUTION OF MAN.

I. Measuring Instruments.—A description of the instruments of precision required for the measurements of the body or in testing its functions. DR. BEDDOE.

II. Form and Size.—Instructions for measuring and describing the form of the body in living subjects, as also skeletons and skulls. Instructions for estimating the relative size of the parts of the body in individuals of different races as well as of the same race living in different climates or under different conditions, and the best order of making a table of results and of determining averages. DR. BEDDOE.

III. Anatomy and Physiology.—Questions relating to the soft parts of the body, organs, muscles, circulation, respiration, temperature, nerves, tissues, &c. DR. BEDDOE.

IV. Development and Decay.—Relating to the periods of growth and development of the body, length of life, child-bearing, puberty, menstruation, dentition, decay, growing grey, death-rate, birth-rate. DR. BEDDOE.

V. Hair.—Relating to the texture and qualities of the hair. DR. BEDDOE.

VI. Colour.—Questions as to the colour of the skin, hair, and eyes, with directions for the use of M. Broca's tables, which will be included in this section. DR. BEDDOE.

VII. Odour.—Relating to the peculiar smell of the body of different races, whether natural and constitutional, or merely the result of filth. DR. BEDDOE.

VIII. Motions.—Muscular peculiarities, such as the power of moving the ears, scalp, use of toes in holding objects, agility, climbing. DR. BEDDOE.

IX. Physiognomy.—Questions as to the expression of the countenance, natural gestures, blushing, &c., with instructions for taking the form of features. See also No. XCVIII. CASTS. C. DARWIN.

X. Pathology.—Diseases, as well as alterations of the powers produced by mode of life, use, disuse, climate, &c.; recuperative powers, healing of wounds. DR. BEDDOE.

XI. Abnormalities.—Natural deformities, such as steatopyga, albinism, erythrism, &c., not including DEFORMATIONS, which come under the second part—CULTURE. DR. BEDDOE.

XII. Physical Powers.—Instructions for testing strength, speed, endurance. DR. BEDDOE.

XIII. Senses.—Instructions for testing the powers of the senses—sight, hearing, sense of smell, touch, &c. DR. BEDDOE.

XIV. Heredity.—Inheritance of qualities, both physical and mental. F. GALTON AND DR. BEDDOE.

XV. Crosses.—Fertility and character of half-breeds, shades of colour and other peculiarities produced by crossing, continuance of fertility in descendants. DR. BEDDOE.

XVI. Reproduction.—Numbers of family, numbers at birth, proportion of sexes, &c. DR. BEDDOE.

XVII. Psychology.—Quickness of perception, power of reasoning, learning, generalizing, memory, perseverance. DR. BEDDOE.

Part II.—Culture.

XVIII. History.—Known facts regarding the history of races, name by which they call themselves, their migrations, their traditions concerning themselves, and mode of recording past events. E. B. Tylor.

XIX. Archæology.—Inquiries into the monuments and other relics of a past age, with the ideas of the people concerning them. Col. Lane Fox.

XX. Etymology.—Information obtainable from the derivation of words, names of places, rivers, &c. E. B. Tylor.

XXI. Astronomy.—Knowledge of the people concerning it. Division of time. Names of the stars, with their meanings. Astrology. F. Galton.

XXII. Arithmetic.—Extent and knowledge of numbers. Method of notation by fives, tens, twenties, &c. Analysis of compound numerals. Names of numbers. E. B. Tylor.

XXIII. Medicine.—Knowledge of simples and medical remedies. Superstitions connected with the healing art. Charms and ceremonies used in sickness. Sanatory measures. Treatment of sick. Dr. Barnard Davis.

XXIV. Food.—Articles used as food; mode of cooking. Manufacture of wine, beer, &c. Quantity eaten. Comparison of native dietary with law of diet. A. W. Franks.

XXV. Cannibalism.—Its causes, frequency, motives for, and circumstances under which it either is or has been practised. A. W. Franks.

XXVI. Narcotics.—Use of tobacco, snuff, hemp, Siberian mushroom, betel, coca, &c.; forms of pipes and snuff-cases, ceremonies and practices connected therewith; effects, purposes for which used, &c. A. W. Franks.

XXVII. Crimes.—Acts regarded as criminal, whether against person, property, or religion, stranger, slave, or chief, &c., and the reasons why they are so regarded. E. W. Brabrook.

XXVIII. Morals.—Acts recognized as right and wrong in family and public life; chastity, honesty, sobriety, truthfulness, &c. E. B. Tylor.

XXIX. Fetishes.—Description and history; whether worshipped as emblems or otherwise; mode of carrying; superstitions and ceremonies connected with. E. B. Tylor.

XXX. Religions.—Nature of deities, whether ancestral, elemental, or typical. Beliefs concerning souls and spirits, their forms and actions; description and meaning of religious ceremonies—sacrifice, purification, &c.; position of women in relation to religion. E. B. Tylor.

XXXI. Superstitions.—All superstitions not included under any special section. E. B. Tylor.

XXXII. Witchcraft.—Evil eye, possession by devils, spells, &c., with the ordeals and punishments connected with them. E. B. Tylor.

XXXIII. Mythology.—Including folk-lore. E. B. Tylor.

XXXIV. Government.—Appointment and government of chiefs, and offices of subordinate rank, whether hereditary or otherwise. E. W. Brabrook.

XXXV. Laws.—Including game-laws; laws relating to land, inheritance, administration of justice, punishments, fines, &c. E. W. Brabrook.

XXXVI. Customs.—It may be difficult in some cases to distinguish between laws and customs, but they should be defined when practicable. E. B. Tylor.

XXXVII. Taboo.—Its origin, history, customs, and superstitions connected with it. E. B. Tylor.

XXXVIII. Property.—To what extent private property is recognized;

personal and landed property. Tenures of land, customs concerning, &c.; individual, family, and common property. Heirship, succession to.

XXXIX. Trade.—Mode of barter and exchange in all its phases; conveyance of articles from a distance by means of barter. HYDE CLARKE.

XL. Money.—Including all objects recognized as mediums of exchange, and gradual development of the idea of a standard currency; relative value of. HYDE CLARKE.

XLI. Weights and Measures.—Accurate descriptions of, referred to European standards; effects of the absence of. HYDE CLARKE.

XLII. War.—Tactics; causes of; description and names of weapons; mode of conducting, effects, &c. COL. LANE FOX.

XLIII. Hunting.—Including fishing; trapping, mode of; customs connected with; weapons and instruments employed. COL. LANE FOX.

XLIV. Nomadic Life.—Its causes and effects; mode of conducting the migrations.

XLV. Pastoral Life.—Questions especially relating thereto.

XLVI. Agriculture.—Causes which have led to; mode of tillage; instruments; cultivated plants; effect of, &c.

XLVII. Training Animals.—Skill in; mode of; animals trained; fondness for pets, &c.

XLVIII. Slavery.—Causes and effects of; degree of bondage; treatment; rights of slaves; position in family; price of slaves; whether war captives or others; whether increasing or diminishing.

XLIX. Social Relations.—Including family life; treatment of women, children, &c.

L. Sexual Relations.—Marriage, polygamy, polyandry, exogamy, endogamy. SIR J. LUBBOCK.

LI. Relationships.—Mode of estimating, as treated by Sir J. Lubbock; genealogy; number of generations of which correct record is maintained. SIR J. LUBBOCK.

LII. Treatment of Widows.—Customs relating thereto. SIR J. LUBBOCK.

LIII. Infanticide.—Causes and effects of practices relating thereto. SIR J. LUBBOCK.

LIV. Causes that limit Population.—Description of. F. GALTON.

LV. Education.—Mode of training children; aptitude for; effects of; absence of, &c. F. GALTON.

LVI. Initiatory Ceremonies.—Account of; causes of. F. GALTON.

LVII. Games.—Amusements of all kinds; aptitude for; whether indigenous or derived. F. GALTON.

LVIII. Communications.—Roads, paths, how made; absence of; transport animals employed; mode of carrying burdens; bridges, ferries, &c. F. GALTON.

LIX. Tattooing.—Drawings and descriptions of all tattooing and painting of the body and cicatrices; periods when performed, &c. A. W. FRANKS.

LX. Clothing.—Description of; construction; mode of wearing; distinctions of; penis-cases, &c. A. W. FRANKS.

LXI. Personal Ornaments.—Necklaces, bracelets, anklets, feathers, nose-rings, ear-rings, cap-ornaments, how made and worn. A. W. FRANKS.

LXII. Burials.—Including customs at death; objects deposited with the dead; reasons assigned for; food deposited with; ceremonies at. See also No XXX. RELIGIONS. W. GREENWELL.

LXIII. Deformations.—Artificial deformations of the body; reasons for; mode of treatment, &c. PROF. BUSK.

LXIV. Tribal Marks.—Including all party badges, whether worn on the person or otherwise; origin of heraldry, &c. A. W. FRANKS.

LXV. Circumcision.—Mode of practising; reasons for; ceremonies connected with, &c.

LXVI. Totems.—Description of. J. F. M'LENNAN.

LXVII. Dyeing.—Including the manufacture and use of all paints and dyes. J. EVANS.

LXVIII. Music.—Description of musical instruments; characteristics of music, &c. PROF. CARL ENGEL.

LXIX. Language.—Including phonetic sounds which can and cannot be pronounced; use of the "Outline Dictionary" of Professor Max Müller. E. B. TYLOR.

LXX. Poetry.—Characteristics of; use of words in exact; nature of metre; nonsense choruses; notions of drama. E. B. TYLOR.

LXXI. Writing.—Including also curves, marks, and tallies; scoring; picture writing; hieroglyphics in every stage of development. E. B. TYLOR.

LXXII. Drawing.—Including sculpture, modelling, and representative art of all kinds, with illustrations. COL. LANE FOX.

LXXIII. Ornamentation.—Inquiries into the history and development of all the various forms of ornamentation. COL. LANE FOX.

LXXIV. Machinery.—Any traces of the economy of labour by means of; querns, hand-mills, water-mills, &c. J. EVANS.

LXXV. Navigation.—Inquiries into the use and history of the forms of boats, paddles, mode of rowing; method of ascertaining courses employed by sea-faring people; use of nautical instruments—whence derived, how and where constructed; sails; seamanship.

LXXVI. Habitations.—Description of houses, huts, tents, and their congregation in towns and villages; also cave-dwellings, buildings on piles, weams, and household furniture. SIR W. ELLIOT.

LXXVII. Fire.—Mode of making and preserving fire, and any customs or superstitions connected with fire. E. B. TYLOR.

LXXVIII. String.—Mode of fabricating string and rope, and the substitutes for it. J. EVANS.

LXXIX. Weaving.—Descriptions of all looms and woven articles; sewing; bark cloth. J. EVANS.

LXXX. Pottery.—Mode of manufacture; materials used; forms; uses; hand-made; wheel-turned; history; glazing pottery. A. W. FRANKS.

LXXXI. Leather-work.—Mode of dressing skins; uses of. J. EVANS.

LXXXII. Basket-work.—Mode of fabricating; forms, uses, &c. J. EVANS.

LXXXIII. Stone Implements.—Fabrication and use of, at the present time; history of. COL. LANE FOX.

LXXXIV. Metallurgy.—Smelting; forging; ores, how found; origin of; uses; blacksmiths, &c.

LXXXV. Miscellaneous Arts and Manufactures.—All arts and manufactures not included under any special heading.

LXXXVI. Memorial Structures.—Erection and object of, at the present time. SIR J. LUBBOCK.

LXXXVII. Engineering.—Dams, canals, palisades, bridges. J. EVANS.

LXXXVIII. Topography.—Notions of geography; map-drawing; knowledge of locality, of foreign countries.

LXXXIX. Swimming.—Mode of; powers of; uses; diving.

XC. Natural Forms.—Questions relating to the use of natural forms in the arts, such as the use of stones as hammers, horns as spears, shells as vessels, animals' hides and scales as armour, &c. COL. LANE FOX.

XCI. Conservatism.—Fondness for tradition; questions relating to the preservation of old customs and forms of art which throw light on the length of time they may have continued in use. E. B. TYLOR.

XCII. Variation.—Changes of fashion; observations of minute varieties in customs and forms of the arts, by means of which gradual progress may have been effected. E. B. TYLOR.

XCIII. Invention.—Notices of independent inventions. E. B. TYLOR.

Part III.—MISCELLANEOUS.

XCIV. Population.—Instructions for estimating the population of a district. F. GALTON.

XCV. Contact with Civilized Races.—Influence of civilization on aborigines. Causes of decay when in contact with the whites; whether racial or social. SIR T. GORE BROWNE.

XCVI. Preserving Specimens.—Instructions for preserving human and other remains. DR. BARNARD DAVIS.

XCVII. Anthropological Collections.—Instructions for obtaining, preserving, and disposing of. A. W. FRANKS.

XCVIII. Casts, &c.—Instructions for taking casts of objects, rubbings, inscriptions, and antiquities, &c.; masks of faces, &c. A. W. FRANKS.

XCIX. Photography.—Instructions for the use and transport of photographic apparatus.

C. Statistics.—Instructions as to the mode of obtaining them. F. GALTON.

Preliminary Note from the Committee, consisting of Professor BALFOUR, *Convener,* Dr. CLEGHORN, Mr. ROBERT HUTCHISON, Mr. ALEXANDER BUCHAN, *and* Mr. JOHN SADLER, *on the Influence of Forests on the Rainfall.*

AFTER some inquiry and correspondence the Committee heard of two localities, viz. Carnwath, Lanarkshire, and Abernethy, Speyside, Morayshire, which seemed likely to be suitable stations for carrying on the inquiry entrusted to them, owing to wood likely to be cut down soon, and assistance expected from the proprietors. The station in the Speyside district the Committee have not yet been able to visit; but a Subcommittee, consisting of Dr. Cleghorn and Mr. Buchan, visited Carnwath on the 11th of July, 1873.

Carnwath has been one of the stations of the Scottish Meteorological Society since the beginning of 1869, and, through the liberality of Hector F. M'Lean, Esq., Carnwath House, is supplied with a full equipment of instruments, all of which have been compared. The observer is Mr. William Currie, Clerk to Mr. M'Lean. He was formerly observer at Eallabus, Islay, and is, in the opinion of Mr. Buchan, in every way one of the best observers of the Scottish Meteorological Society.

Three stations were placed at the disposal of the Committee, and Mr. M'Lean offered most handsomely to cut down the trees at the station which should be selected, at the time and in the quantity which would, in the opinion of the Committee, best suit the objects of the inquiry.

The three localities were visited by the Subcommittee, who had no difficulty in fixing on one of these as the best. Its situation is shown on a plan, traced from the Trigonometric Survey. [This plan was exhibited at the Meeting.]

At the point marked I. is placed the anemometer of the station, on the top of a grassy knoll, free to the winds all round. At a distance of 320 yards to the S.S.W., at point marked II., in centre of patch coloured red, is a wooded knoll precisely similar and nearly of the same height. Immediately on west of top of this knoll is a circular patch 50 feet in diameter, quite clear of trees, covered with a fine, close, grassy sward, containing well-grown specimens of *Veronica officinalis*, *V. chamædrys*, *Galium saxatile*, *Potentilla*, *Tormentilla*, *Ranunculus acris*, and a few roots of *Lastrea Filix-mas*.

Trees (mixed, but chiefly pines) from 30 to 40 feet high surround this patch on all sides. The extent of woodland in which it is proposed to place the station is $62\frac{1}{4}$ acres; but there is a much greater extent of woodland in the neighbourhood.

The Committee propose to erect two sets of instruments—one beside the anemometer at I., the other in the centre of the open space of the wooded knoll at II., each set to be in every respect alike, and to consist of the following:—

1 Maximum Thermometer.
1 Minimum Thermometer.
1 Dry- and Wet-bulb Hygrometer.
1 Stevenson's Louvre-boarded Box, for holding the thermometers.

The instruments to be read twice daily, viz. at 9 A.M. and 9 P.M., in connexion with those at the station of the Scottish Meteorological Society at the point marked III., and always in the same order.

It is proposed, for one year at least, to compare the observations on the wooded and naked knolls, and to cut down none of the trees; and it is also proposed to delay the planting of rain-gauges at I. and II. until a sufficient space has been cleared around II. by cutting, the Committee being of opinion that observations from a gauge planted in the small patch of II. surrounded with trees 30 to 40 feet high, and at no greater distance than 25 feet, would give results worse than useless.

The Committee hope, in the course of a few months, to be able to make arrangements for the establishment of the second station at Speyside, where the forests are pure Scotch fir of magnificent growth, for which instruments similar to those procured for Carnwath will be required. To meet this outlay and the payment of observers, the Committee will require a renewal of the grant of £20 from the British Association for 1873–74.

Appendix added by the Committee, 2nd March, 1874.

The Committee are of opinion that the problem of the Influence of Forests on the Rainfall cannot be directly attacked, but must be preceded by a preliminary inquiry into the temperature and humidity of the air of the forest itself, as compared with the temperature and humidity of the air outside the forest. The observations referred to above will supply these data. The Committee also contemplate the placing of underground thermometers and evaporometers at Stations Nos. I. and II., and the examination of the temperature of the trees by means of thermometers permanently fixed in them, in the manner adopted at the forest-stations of Bavaria.

Report of Sub-Wealden Exploration Committee, appointed at the Brighton Meeting, 1872, *consisting of* Henry Willett, R. A. Godwin-Austen, *F.R.S.*, W. Topley, *F.G.S.*, T. Davidson, *F.R.S.*, J. Prestwich, *F.R.S.*, W. Boyd Dawkins, *F.R.S.*, *and* Henry Woodward, *F.R.S.* *Drawn up by* Henry Willett *and* W. Topley.

The proposal to commemorate the visit of the Association to Brighton by some practical effort to extend the bounds of scientific knowledge was received with unexpected favour, and the support given to the Sub-Wealden Exploration has justified its selection as the most eligible unsolved scientific problem in the south-east of England. This Report may be considered a summary of the transactions more fully detailed in the four quarterly reports of the Honorary Secretary.

The original project was for a bore of $6\frac{1}{2}$ inches; but this was overruled by the Committee in London, and the adoption of a diameter of 9 inches was decided on. The opinion of French engineers of eminence was adduced by Joseph Prestwich, Esq., F.R.S., F.G.S., in favour of this increase, and probable success to the ultimate depth required was considered more important than the increased cost. The bore-hole has reached (at the full diameter of 9 inches) a depth of 300 feet, and the engineer has contracted to increase it to the depth of 418 feet at the cost only of £1 per foot. The diameter of 9 inches may be considered merely the foundation of the work, and, like all foundations, it makes but a small show for the money expended.

The shedding, machinery, tools, and rods for a depth of nearly 1000 feet have been purchased, but much time and money must be expended before 2000 feet or palæozoic strata are reached.

300 feet of strata have already been examined: 70 feet are supposed to represent the known Rounden-Wood beds; 230 feet are new to science, of which 50 feet consist of valuable beds of gypsum.

Professor Ramsay states "no such beds of gypsum have hitherto been found in Europe;" and Mr. Etheridge considers "that it is the most important geological discovery made in England for the last twenty years."

The cores exhibited prove, by their horizontal bedding, that hitherto the crest of the anticlinal axis has been undisturbed, fully justifying the selection of the site. Mr. Topley explains more fully (in his accompanying Report) the general geological features.

It being found impossible to *bore* (and that the drilling by the T chisel in ordinary use so crushed up the *débris* as to baffle examination), the Honorary Secretary designed a novel form of drill possessing the following advantages :—

1st. It cuts only the circumference.
2nd. It makes better progress.
3rd. The central core is left intact.
4th. The tool not unfrequently extracts the core itself.

The gypsum shown was thus extracted. No such cores have, it is believed, in this country been brought to the surface from similar depths.

A plan of an ingenious form of electromagnet for the extraction of broken pieces of steel from the bottom of the bore-hole was exhibited. It was suggested by J. R. Capron, Esq., of Guildford, and designed by Professor John Tyndall, F.R.S., assisted by Messrs. Tisley and Spiller.

The question of cost is a serious one. The only definite contract for continuing the work from a depth of 218 feet to 1500 feet (including the use of the tools, machinery, engine, &c. belonging to the Committee) was over £5000. When an application for a grant was made in 1872 a large sum was not asked for, and it was deemed more consistent to await the first year's report; not only has the £25 voted been expended, but over £2000 has been subscribed by other parties, all of which will have been expended before the expiration of the current year; large additional subscriptions will therefore be required.

A reference to the names forming the Central Committee will convince that the best method for ultimate success will be adopted.

It is therefore hoped that the Association will consider it advisable to reappoint the Committee, and to vote an increased grant for the prosecution of the work.

In addition to the actual cost of the work of the boring, the expense incurred has much exceeded the estimate. This excess is attributed to the following causes, many of which will not again occur :—

I. The increased diameter of the bore.
II. The distance travelled by the engineer.
III. The cost of shelter in so exposed a situation, it being impossible to get men to work without it.
IV. The cost of carriage, from the inaccessible nature of the roads &c.
V. The large increased cost of fuel.
VI. The necessity of providing forge, tools, &c. in anticipation of future demands.
VII. The original expenses of survey and commencement.
VIII. Printing and postage in soliciting subscribers.

Geological Report, drawn up by W. Topley, F.G.S., of the Geological Survey of England and Wales.

Hitherto almost all borings have been made for the purpose of solving some probable anticipation, or for the discovery of something definitely required, as coal or water. In such cases, if the object sought for be found, the boring is said to be successful; if not, it is said to have failed. With the Sub-Wealden boring, however, failure can only arise by a premature arrest of the

work, either by an accident to the bore-hole or from want of funds. Should the boring be continued, the result, whatever it may be, will be a success. It is important that this should be once more distinctly stated, for the Sub-Wealden boring is too often spoken of as a "search for coal;" so that, should coal not be found, we shall certainly be told that our project has failed, and that so much money has been thrown away by ignorant theoretical speculators.

Now, while the originators of this undertaking, as well as the members of this Committee, are fully alive to the immense national benefit which would result from the discovery of coal in the south-east of England, they do not put this forward as the primary object, nor has any money been solicited with any such intention. The sole object of the exploration is to discover what beds underlie the Wealden, and especially to reach the Palæozoic rocks. This we have every reason to hope will be done; and whatever those rocks may prove to be, if we can only reach them, the Sub-Wealden exploration will then have been a success.

Should the Association think fit to renew the grant and to reappoint the Committee, we may confidently hope that future Reports will contain important additions to our knowledge of the geology of the south-east of England. The present Report must be regarded merely as a preliminary one; and it may be well at this stage to refer to some general questions, and to clear the way for future Reports.

Dr. Mantell was the first geologist who carefully studied the interior of the Weald. He divided the Hastings beds (or Hastings sands, as they were then called) into four divisions:—

Horsted Sand.	Worth Sands.
Tilgate beds.	Ashburnham beds.

When the geological survey of the Weald was first commenced, Dr. Mantell's terms and divisions were adopted; but it was soon found that they were inapplicable in some parts. The classification adopted by the Survey is that proposed by Mr. Drew, whose account of it was laid before the Geological Society in 1861.

Unfortunately the Survey retained Dr. Mantell's term (Ashburnham beds) for the lowest strata, and followed him in considering the limestone beds of Poundsford to be the same as the mottled clays, which are the lowest strata seen on the coast. Not only are the limestone beds of Poundsford below the clays of Fairlight, but neither of these are the equivalents of the strata at Ashburnham itself, which lie near the bottom of the Wadhurst Clay. Near the base of this clay, and lying in or near to the nodules of clay ironstone, which were formerly extensively worked, there is a bed of ferruginous limestone crowded with *Cyrenæ*. Dr. Mantell thought this to be identical with the shelly limestone found near Poundsford; and wherever he met with it he noted the occurrence of Ashburnham beds. Many of the localities mentioned are certainly in Wadhurst Clay.

In Dr. Fitton's opinion, the strata of Poundsford, Archer's Wood, &c. were lower than any others in the Weald; and he adds:—"From the general structure of the tract surrounding Brightling, the ravines at the base of the prominence on which the Observatory stands ought evidently to afford the lowest strata of the country"*.

A detailed survey of the entire district has proved that he was correct, and that it is just at this spot (in Rounden Wood) that the lowest strata are brought to the surface. More recent examination of the district has deter-

* Geology of Hastings, p. 54 (1853).

mined the Director of the Survey to separate these beds. The clays of the coast are now called "Fairlight Clays" (Mr. Gould's term), while the lowest limestone series of the inland district are coloured as Purbecks.

The difference in the strata rendered such a change in the classification desirable, and it has been confirmed by the discovery of thick beds of gypsum in the Sub-Wealden boring. Although found in detached blocks in the Purbeck beds of Dorsetshire, gypsum was unknown before in the Weald. It should also be noticed that the Ashdown Sand, which comes between the Fairlight Clays and the Wadhurst Clay, is only about 150 feet thick at Hastings; but the Ashdown Sand of the Brightling district (including under that term all the strata intervening between the Wadhurst Clay and the Purbecks) is 300 or 400 feet thick. We may then fairly assume that the lower part of these sands (which is much more clayey than the upper part) represents the Fairlight Clays of the coast.

In classing these beds with the Purbecks we are only repeating the opinion of Mr. Conybeare (the earliest geological writer on the district). Subsequently they have been referred to the Purbecks by Sir H. De la Beche, Prof. Edward Forbes, Dr. Fitton, Mr. Godwin-Austen, and others; in some cases even by Dr. Mantell himself.

The Purbeck beds of Sussex consist chiefly of clays and shales. The limestones are chiefly found upon two horizons—an upper one, called "the greys" or "the vein-greys," and a lower one, called "the blues." These are separated by about 100 or 140 feet of shales, interspersed with only a few thin beds of limestone and a little sandstone. Below the "blues" are impure limestones (bastard blues). The lowest strata known previous to the boring were the "dunk shaws," thin flaggy limestones found in Rounden Wood, crowded with *Cypridea valdensis*.

The total thickness hitherto known may be estimated at a little over 300 feet.

The boring at Netherfield began at a point about 250 feet down in the Purbecks, just below the "blues." Mr. Willett and Mr. W. Boyd Dawkins proposed the site ultimately chosen; and no other spot in the district would, all things considered, have presented equal advantages.

The strata passed through up to the present time (September 1873) are as follows:—

Strata.	Thickness.		Depth from surface.	
	ft.	in.	ft.	in.
Shales	16	6	0	0
Blue limestone	2	6	19	0
Shale	5	0	24	0
Blue limestone	2	0	26	0
Shale	4	0	30	0
Limestone	1	6	31	6
Shale	4	0	35	6
Limestone	3	0	38	6
Shale	4	0	42	6
Limestone	4	0	46	6
Hard blue shale	15	6	62	0
Hard grey shale	3	0	65	0
Hard shale	14	6	79	6
Shales, with crystals of carbonate of lime	9	0	88	6
Grey shale	13	0	101	6
Greenish shales, with gypsum veins	20	0	121	6
Impure gypsum	8	6	130	0
Pure white gypsum	4	0	134	0
Impure gypsum	5	6	139	6

Strata.	Thickness. ft. in.	Depth from surface. ft. in.
Pure white gypsum	3 0	142 6
Gypsum, more or less pure, hard, and dark	14 6	157 0
Blue shale	3 6	160 6
Gypsum, in nodules and veins	12 0	172 6
Gypseous marl	6 6	179 0
Sandy marl	0 6	179 6
Black sulphurous shale	0 6	180 0
Greenish sand, with nodules of black chert	21 0	201 0
Sandy shale	30 0	231 0
,, with more or less variations of calcareous matter, and with interspersed chert-nodules	8 0	239 0
Carbonate of lime, in veins intersecting ditto	2 0	241 0
Indurated black sandy shale, very sulphurous	12 0	253 0
Blacker ditto; softer	7 0	260 0
Harder shales, with much chert	12 0	272 0
Black horizontal shale, very sulphurous	2 0	274 0
,, ,,	12 0	286 0
Shale, paler in colour, with veins of gypsum	4 0	290 0
Shale, darker and more sandy	2 0	292 0
Shale	2 0	294 0

The higher beds marked as "limestones" in the boring-section are mostly impure. These are the "bastard blues." Below these, in Rounden Wood, there are other limestones known as the "Rounden greys," and then come the "Dunk shaws." The "greys" and "blues" are easily identified by the workmen whenever they occur. The "Dunk shaws" are peculiar in character; but as neither they nor the "Rounden greys" have been identified in the boring, they may be a local peculiarity. The new discovery of gypsum is an important addition to the Purbeck series of Sussex. The two principal beds of gypsum consist of perfectly white alabaster. The gypseous shales are dark in colour, but they contain so much gypsum that, when pulverized, they appear almost white. The gypsum is mostly evenly bedded; but that found in the shales is nodular and irregular in structure. It is not improbable that at or near this horizon gypsum will occur over a considerable area in the Sussex Purbecks; and it probably occurs not far below the surface at the bottom of the "rough field" in Rounden Wood.

With regard to the depth at which the Palæozoic rocks are likely to occur beneath the Weald, I may remind you that 700 feet has been mentioned as a probable minimum, and 1700 feet as a probable maximum. It would seem, from borings already made in other districts, that the depth of the palæozoic floor below the present sea-level is to a large extent independent both of the newer formations above it and of the apparent disturbances which are supposed to have affected them. The borings at Kentish Town, Harwich, Ostend, and Calais, all reach the palæozoic floor at a depth only slightly exceeding, or slightly less than, 1000 feet below the sea-level; and in these cases the higher strata passed through are of very varying character and thickness. These, however, are all on, or to the north of, the supposed westerly extension of the "Axis of Artois," and it is possible that different conditions prevail to the south of that line.

I may also remind you that, in the Pays de Bray, Carboniferous Limestone occurs at a depth of 59 feet from the surface, underlying Kimmeridge Clay. It is this presence of the Carboniferous Limestone in this position which gives some slight hope of the occurrence of Coal-measures near Boulogne and in our Wealden area further west. Mr. Godwin-Austen has pointed out that

the general dip of the Carboniferous Limestone of the Boulonnais is to the south; and this is the dip where they are last seen passing beneath the unconformable secondary rocks. As Carboniferous Limestone occurs under the Pays de Bray, it is not unlikely that some Coal-measures may be preserved in a palæozoic trough between these places.

Report of the Committee, consisting of Mr. FRANCIS GALTON, Mr. W. FROUDE, Mr. C. W. MERRIFIELD, *and* Professor RANKINE, *appointed to consider and Report on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore.*

IN consequence of the death of one of our number, the late lamented Professor Rankine, and the pressing occupations of the other members of the Committee, it has not been possible to make much progress with this subject during the past year, and they are not at present prepared to report upon it.

Report of the Committee on Science-Lectures and Organization,—the Committee consisting of Prof. ROSCOE, *F.R.S.* (Secretary), Prof. W. G. ADAMS, *F.R.S.*, Prof. ANDREWS, *F.R.S.*, Prof. BALFOUR, *F.R.S.*, F. J. BRAMWELL, *F.R.S.*, Prof. A. CRUM BROWN, *F.R.S.E.*, Prof. T. DYER, Sir WALTER ELLIOT, *F.L.S.*, Prof. FLOWER, *F.R.S.*, Prof. G. C. FOSTER, *F.R.S.*, Prof. GEIKIE, *F.R.S.*, Rev. R. HARLEY, *F.R.S.*, Prof. HUXLEY, *F.R.S.*, Prof. FLEEMING JENKIN, *F.R.S.*, Dr. JOULE, *F.R.S.*, Col. LANE FOX, *F.G.S.*, Dr. LANKESTER, *F.R.S.*, J. N. LOCKYER, *F.R.S.*, Dr. O'CALLAGHAN, *LL.D.*, *D.C.L.*, Prof. RAMSAY, *F.R.S.*, Prof. BALFOUR STEWART, *F.R.S.*, H. T. STAINTON, *F.R.S.*, Prof. TAIT, *F.R.S.E.*, J. A. TINNÉ, *F.R.G.S.*, Dr. ALLEN THOMSON, *F.R.S.*, Sir WILLIAM THOMSON, *F.R.S.*, Prof. WYVILLE THOMSON, *F.R.S.*, Prof. TURNER, *F.R.S.E.*, Prof. A. W. WILLIAMSON, *F.R.S.*, *and* Dr. YOUNG.

[Read at the Brighton Meeting.]

YOUR Committee endeavoured in the first place to obtain a clear view into the nature and extent of their possible sphere of action, as defined in the two following Resolutions, by which they were appointed at the Meeting at Edinburgh:—

1. To consider and report on the best means of advancing Science by Lectures, with authority to act, subject to the approval of the Council, in the course of the present year if judged desirable.
2. To consider and report whether any steps can be taken to render scientific organization more complete and effectual.

In this endeavour your Committee have been greatly aided by the following statement handed in by Dr. Joule, clearly pointing out the general objects which should be aimed at in Science Organization in this country.

Dr. Joule's Statement.

In order to render scientific organization as complete and effectual as a great nation may rightly demand that it should be, it is essential to obtain the authority of and material assistance by Government. This view is evidently in harmony with that which has been adopted by the country respecting national education. Indeed the education of the people in the rudiments of knowledge will prove comparatively useless if the higher developments are not fostered with at least equal care.

The following are some of the principal objects to be obtained by a more complete organization, for which Government aid is imperatively demanded:—

1. Observatories for the continual watching of
   a. Astronomical phases.
   b. Meteorological phenomena, including Magnetism of the Earth.
   c. Tides and Sea-level.
2. Museums for permanent collections of
   a. Specimens in Natural History.
   b. „ Chemistry.
   c. „ Geology and Mineralogy.
   d. Manufactured products.
   e. Machines, tools, &c.
   f. Scientific Apparatus.
3. Libraries of books on Science, comprising the Transactions of British and Foreign Societies.
4. Publication of complete classified catalogues of scientific researches, inventions, and discoveries in this and other countries.
5. Scientific researches.
6. Inquiries, at the instance of Government, respecting
   a. Artillery, Ships, Fortifications, &c.; also
   b. Mines, Adulterations, Sanitary matters, &c.
7. Scientific Expeditions.
8. Verification and issue of Scientific Instruments.
9. Scientific Instruction by
   a. The Foundation of Chairs.
   b. Popular Lectures.
10. Rewards for discoveries, researches, and inventions.

The first of the above objects has been treated of by Professor Balfour Stewart. It is most desirable that thoroughly efficient observatories should be established in various localities of the British empire.

Complete museums and libraries should be founded and scientific instruction provided in all the centres of large populations. It is impossible to be satisfied with national collections in the metropolis only, and with instruction supplied in a few and sometimes ill-chosen localities, when we regard the present wants of society.

The fourth object has been undertaken by the Royal Society. It is, however, absurd to expect that it can be attained in the completeness which is absolutely essential to the progress of science without the continuous supply of ample funds.

Government has already done something to promote the fifth object, especially by its grant to the Royal Society. The result has certainly been to encourage further steps in the same direction. The same remark applies to the seventh object.

The sixth object is of immediate concern to the State. At the present day, when war has been raised from an art to a science, it would be the height of folly not to secure the best theoretical talent that the country can afford. Under the head (*b*) it may be remarked that the commonest feelings of humanity call for authoritative and intelligent interference with arrangements and processes by which the lives and happiness of so many are so frequently imperilled.

The verification and issue of scientific instruments is a most important duty, and ought to be undertaken by a body armed with authority sufficient to secure the use not only of instruments which are correct, but whose indications are on a uniform system of units. The duty of verification has been undertaken by the Kew Observatory with such good results as to encourage further efforts over a wider field.

The objects proposed are extensive, and would involve some difficulty in carrying them into effect. But the benefits to be attained are so immense that these considerations should not be allowed to weigh. Moreover, existing Societies, several of which possess a very complete organization, would supply a great deal of the necessary machinery, so that the chief business of the Government would be to supervise, give authority, and furnish the necessary funds*.

Your Committee, believing that the only mode of making progress in so wide a field as that described by Dr. Joule was to select some few points upon which to commence action, determined to appoint three Subcommittees for the purpose of taking up the discussion of three of the above-named objects.

Subcommittee A.—To discuss and report on the first of the resolutions under which the Committee was appointed, viz. the best means of advancing Science by Lectures.

Subcommittee B.—To discuss and report on the question of Scientific Organization as regards Meteorology.

Subcommittee C.—To discuss and report on the question of Scientific Organization as regards Local Scientific Societies.

Reports from the above Subcommittees have been received; their substance is as follows:—

Subcommittee A.—On the best means of advancing Science by Lectures.

In accordance with the first original resolution, the Council of the Association, on February 28th, 1872, gave permission to the proposed action of your Committee as regards Science-Lectures. The Subcommittee A was charged with the preparation for one year of a list of lectures for the consideration of your Committee, and with the task of communicating with the various towns with the view of establishing a system of Science-Lectures throughout the country. The necessity of establishing some regulation under which the names of proposed Lecturers should be selected became at once apparent. The following regulations were ultimately adopted:—(1) The names of the Lecturers to be selected (with their consent) from Members of the General Committee of the Association, or from amongst the Graduates of any University of the United Kingdom. (2) The subjects of the Lectures shall be such as are included in one or other of the Sections of the Association. Circulars were then sent to a certain number of gentlemen asking for their cooperation in the delivery of Science-Lectures in various parts of the

* See Lord Wrottesley's Address to the Royal Society, Nov. 30, 1855; also Report of the Parliamentary Committee to the British Association at Glasgow, 1855.

kingdom. It is clearly understood, and distinctly stated in the circular, that neither your Committee nor the Association can be in any way responsible for the pecuniary arrangements which must in each case be made between the Lecturer and the Institution or persons engaging his services. It is also not intended to publish the list of Lecturers, but simply to send the same to the various Institutions who may apply for information. The Subcommittee have received many promises of assistance from many eminent and well-qualified lecturers; the list is, however, not yet completed, and, owing to the difficulty of getting the several members resident in the country to meet together, it has not been possible as yet to open any communication with the various towns or institutions as to the further spread of the Science-Lectures throughout the country; it is, however, hoped that speedy action in this direction may be taken. Your President, Dr. Carpenter, has taken special interest in this branch of your Committee's proceedings; and he writes that he is sure, from applications which he is continually receiving, that an organization for the promotion of Science-Lectures would do great service by facilitating arrangements between such as want them and such as can efficiently supply the want, and by making known what experience shows to be the best *method*.

Subcommittee B.—On Science-Organization as regards Meteorology.

The following statements from Professor Balfour Stewart [embodying certain remarks of Mr. Baxendell] and from Mr. Lockyer, containing their opinion as to the present condition of Meteorological Science, have been received by your Committee.

Prof. Stewart's Statement.

The subject under the consideration of the Subcommittee is a very extensive one, and I am not prepared at this moment to present any thing like a complete statement of the subject; nevertheless there are two very pressing wants of observational science to which I think attention ought to be directed without delay, and which I therefore beg to bring before the Subcommittee. The *first* of these refers to aid in meteorological investigations. There is probably no science which depends more for its progress upon the patient and laborious reduction and discussion of numerous and extensive series of observed facts than that of meteorology. Hundreds of valuable series of meteorological observations, some of them extending over long periods of years, have been made and published, at a great cost of both time and money; but hitherto no results have been obtained from them at all proportionate to the enormous outlay they have involved, the reason being that the close application and labour and expenditure of time required to carry out meteorological investigations are usually much greater than private individuals can afford to devote to them. It is therefore absolutely necessary for the interests of the science that State aid should be given to scientific men who are willing to undertake meteorological investigations of the nature of reductions, provided they can show that the objects they have in view are of sufficient importance to justify a moderate expenditure in endeavours to attain them—this aid to be given in the form of pecuniary grants, to defray the expense of engaging assistants to make such reductions and tabulations of observations and results and such computations as the nature of the investigations may require. If proper representations were made to Government on this subject, there is little doubt that something would be done;

for Government are at this moment largely subsidizing the observational part of meteorology.

It is, however, very evident that unless the facts so accumulated can be thrown open sufficiently to men of science their use will be limited. In the establishment of the Meteorological Office, Government have virtually allowed that the proper maintenance of a sufficient number of observing-stations cannot be expected from private means ; but they appear to have forgotten that it is also necessary to open up these observations to men of science, and to provide the necessary means for discussing them.

When it is considered that it is now an established fact that meteorological changes have more to do with the production of diseases and death than all other known causes, it will be apparent that, besides its uses for the purposes of navigation and in the operations of the agriculturist, a knowledge of the laws and principles of meteorological science has an important bearing upon the welfare of all classes of the community, and that therefore the advancement of meteorology ought to be an object of anxious solicitude to every civilized Government.

The *second* point to which I would direct attention is the bearing of Solar Physics upon meteorology.

Recent investigations have increased the probability of a physical connexion between the condition of the sun's surface and the meteorology and magnetism of our globe.

In the first place, we have the observations of Sir E. Sabine, which seem to indicate a connexion between sun-spots and magnetic disturbances, inasmuch as both phenomena are periodical, and have their maxima and minima at the same times.

On the other hand, the researches of Mr. Baxendell appear to indicate a relation between the daily wind-currents of the earth and its magnetism, and also between the earth's wind-currents and the state of the sun's surface.

In the last place, the researches of Messrs. De La Rue, Stewart, and Loewy appear to indicate a connexion between the behaviour of sun-spots and the positions of the more prominent planets of our system. Whatever be the probability of the conclusions derived from these various researches, they at least show the wisdom of studying together for the future these various branches of observational science.

Now, while a good deal has been done of late years in extending meteorological and magnetical observations, very little has been done in the way of taking daily photographs of the sun's surface. Mr. Warren De La Rue has undertaken, since 1862, the charge of the Photo-heliograph belonging to the Royal Society at the Kew Observatory ; and the Royal Society have hitherto contributed yearly funds from the Government Grant for the working of this instrument ; but this annual grant from the Royal Society is about to expire. Unless, therefore, these solar autographs shall continue to be obtained at private expense, we shall, in February 1872, be without a single station, either in the British Isles or, as far as we know, in any favourable part of the earth's surface, from which any thing approaching to a sufficiently regular production and discussion of sun-pictures is likely to proceed.

It has already been acknowledged by Government, in the formation of the Meteorological Board, that it is beyond the power of private liberality to maintain such regular and long-continued observations ; we therefore trust that they will once more come forward and establish stations in which the sun's surface may be regularly mapped, and the positions and areas of sun-spots regularly measured.

Again, in connexion with these solar researches, it is of importance to know both the heating and actinic effects of our luminary, and how these vary, not only from hour to hour, but from day to day and from year to year. No instrument has, however, yet been devised by which the heating-effect can be conveniently registered. On the other hand, Dr. Roscoe has perfected his method of observing the actinic effect so as to make it automatic; and thus a series of hourly observations of this element of the sun's activity can be very easily obtained. This ought to be done at every station where the surface of the sun is mapped; and we understand that this plan of Dr. Roscoe's is about to be adopted in all Russian observatories. It would thus appear that we are now in a position to define with precision what ought to be done at a sun-station; and, as long as the sun-establishment at Kew lasts, observers may there receive instruction in solar photography through the courtesy of Mr. De La Rue.

They may also receive instruction in the art of measuring the areas and position of sun-spots through the same source; and, finally, Dr. Roscoe will be glad to give the necessary instruction in actinic observations.

It is hardly necessary to remark that the stations should be so selected as, taken together, to be independent of weather, and to be capable of giving at least one picture of the sun's disk every day without the chance of interruption. We know enough of the climate of various places to bring about this result; and in our dependencies, if not in Great Britain, we have a sufficient area from which to choose our stations.

The influence of weather in causing blank days is particularly detrimental in solar research. In the observations lately reduced by Messrs. De La Rue, Stewart, and Loewy, it has been found that a good record of the behaviour of sun-spots, with regard to increase and diminution, as they pass across the disk, is of great value; but that, owing to blank days, this record can only be obtained for half the whole number of spots observed, and even for this half in a more or less imperfect manner. And it is of so much greater importance to select the stations so as to obtain a continuous record, inasmuch as such observations are not like experiments which may be multiplied *ad libitum*; for here we are furnished in a year with a record of a certain number of sun-spots and no more; and it remains with us to make the best possible use of the limited information which nature gives us.

In fine it is believed that a daily record of the sun's surface, accompanied by a record of his actinic power, is, in the present state of science, of the greatest possible importance.

In the preceding remarks no allusion has been made to the establishment of regular spectroscopic observations of the sun's disk—not because it is considered unimportant, but because it forms a separate branch of inquiry, which will be best reported upon by Messrs. Janssen and Lockyer, and by Dr. Huggins, gentlemen who have especially devoted themselves to this subject.

Your Committee have received the following communication on the importance of the establishment of regular Spectroscopic Observations of the Sun's Disk from Mr. Lockyer.

Mr. Lockyer's Statement.

The following are some among the secular inquiries which in my opinion ought to be undertaken at once on a perfectly definite basis and with unswerving regularity. Of course I have not named all the secular inquiries, nor have I alluded to any of the special ones which are suggested almost

every time one looks at the sun. These must be provided for, of course; but the great thing is *not to lose time in starting the work in which time plays the most important part.* I think the future will show that in its broad outline this work is as follows :—

a. *Observations on the Janssen-Lockyer Method.*

Prominences at limb :—

1. Number.
2. Position on sun, with reference to spots and faculæ.
3. Height and brilliancy.
4. Materials.
5. Currents, direction, and velocity.
6. Thickness of lines at top and bottom.

Prominences on sun :—

7. Number.
8. Position (as above).
9. Materials.
10. Rate of elevation or depression.

10A. Width of lozenge.

11. Thickness and brilliancy of lines and associated bright lines in spectrum of photosphere.

Spots :—

12. Lines thickened.
13. Thickness of lines.
14. Alterations of wave-length.
15. Variations of spectrum near spots, including bright lines.

Faculæ :—

16. Thinning and disappearance of lines.
17. Bright photospheric lines.

b. *Observations on Kirchhoff's Method.*

18. Map frequently suspected regions of spectrum to detect changes in Fraunhofer lines.
19. Determine accurately every three or six months the thickness of the principal Fraunhofer lines.
20. Note changes in bright lines.

If the Committee wish, I shall be happy to state at length the reasons which have led me to consider these observations as of high importance and of a secular nature. I may at once, however, very briefly point out, seeing that observations of the spots are considered valuable on all hands, that as the prominences occur in regions where the pressure is less than at the spot-level, they will be likely to afford better indications of the fact of the solar forces being at work; and as there is reason to believe that they are connected with the spots, we shall get more complete evidence in the same direction as that given by the spots. But we may get very much more than this. We now know that the sun's atmosphere extends 10′ at least above the spot-level; we may therefore hope in this way to catch shorter periods than the sun-spot periods. Again, the spectroscope takes us beyond the fact of *forces being at work.* The bright prominences and the lozenges seen on the sun itself, the thickening of lines in spots, and the alterations of wave-length are

unmistakable evidences of what is going on; we get an idea of what forces are at work. But spots are not alone in question.

I say a few words with reference to some of the proposed lines of observation.

Prominences at Limb.

1. This is clearly necessary. We must have a prominence-curve as well as a sun-spot one.

2. In this way we shall be able to do for prominences what Carrington has done for the distribution of the spot in latitude, and in time settle another question about which there is much contradictory assertion among foreign observers at present.

3. For this perhaps C and brilliancy at base should be universally adopted. It will doubtless prove of much importance ultimately to keep to the division of prominences I have proposed in a paper communicated to the Royal Society.

4. Some one line in the case of each element must be taken and kept to. These observations have already given me much evidence of this kind—

$$\begin{aligned}&a,\\&a+b,\\&a+b+c,\\&a+b+c+d;\end{aligned}$$

and the series should be extended as far as possible. The structure of the solar and stellar atmospheres cannot be got at in a more convenient manner than this at present; and as the lines indicate the vapours above the highest level of the photosphere we may look for secular changes.

6. I have already evidence, I think, of change since 1868.

Prominences on Sun.

7, 8, 9, 10, 11. The observations are complementary to those made at the limb.

12, 13. I have already detected changes which are probably connected with the sun-spot period.

18, 19, 20. I have already detected changes.

I think these observations should be made over one of the 11-year periods, under absolutely the same conditions, with the same eyes and instruments, if possible; and even after that time I would rather extend the programme than alter it. The value of each observation will be increased by each additional similar observation.

Of course I expect the chemical end of the spectrum to be photographed. Rutherford and Cornu have shown this to be perfectly feasible in the case of 18, 19, 20. I believe that time and money are alone wanted to do part of all I have put down by photography. It will be an immense gain if this can be done from F, for the region between F and G is terribly trying for the eye. Up to F the eye must naturally be depended on.

Of associated work there will be such researches as explain to us what the various phenomena mean; measures of solar diameter; photographs of sun-spots on a large scale; and eye-observations with a fine instrument to determine whether the changes I have pointed out in the spectra and appearance of sun-spots are connected with the sun-spot period.

I hope my accidental connexion with the new method of work will not cause me to be considered presumptuous if I state my opinion, that if it is

considered necessary to study the sun—the fountain of all our energies—at all, whether for practical ends or for higher objects, the method of local spectroscopic observation must not be neglected. I further believe, as I have before stated, that it helps us where nothing else does, even if the photosphere be alone considered; and that, as we have above the photosphere a region of greater delicacy, the continued study of this will lead us far beyond the point we could hope to attain by merely observing the spots.

While I hold these opinions most strongly, I must also add that I see no way of having the work done by private effort. I have tried hard to continue the work; and in the fact that it was begun in this country by myself I had the strongest inducement to carry it on; but nothing short of one's whole time will suffice for such inquiries.

For the purpose of commencing action in this branch of science, your Committee directed its Meteorological Subcommittee to put themselves into communication with the Observational Establishments of the United Kingdom, with a view of ascertaining from the directors of these establishments what information besides that which they publish, they are willing to communicate to men of science, and on what terms. This has been done with respect to the four following institutions:—

1. The Royal Observatory, Greenwich.
2. The Meteorological Committee.
3. The Kew Observatory Committee.
4. The Stonyhurst Observatory.

The following questions were put to the *Astronomer Royal*:—

1. Might men of science be permitted to inspect the traces of the Greenwich self-recording instruments, especially those recording the changes in terrestrial magnetism and those recording earth-currents, and to take notes of them?
2. Could accurate copies of such traces be procured? and on what terms?
3. Could accurate copies of the hourly tabulated values, taken from such traces, be procured? and on what terms?

To these questions the following reply was received from the *Astronomer Royal*:—

Royal Observatory, Greenwich, London, S.E.,
April 3, 1872.

My dear Sir,—In reply to the questions which you, acting with the British-Association's Committee on Science-Lectures and Organization, have placed before me (received this day), I have to answer as follows:—

1. It will give me great pleasure to offer every facility to any man of science to see, examine, and take notes on all traces of self-recording instruments in this Observatory. I cannot very well allow the sheets to be taken out of the Observatory, and should be glad if persons inspecting these sheets would come at an early hour in the morning.

2. Every facility shall be given for taking accurate copies of the records. If a small number only is required, we will at once have them made (when the specific records are designated) without further trouble to our visitor; if a large number is wanted, some further arrangement may be necessary, on which at present I cannot speak positively.

3. Copies of the tabulated values shall be furnished to any practicable ex-

tent—limited as above, but not so closely, because copying figures is easier than copying curves.

I am, my dear Sir,
Yours very truly,
(Signed) G. B. AIRY.

Professor Roscoe.

The Astronomer Royal was thanked in the name of the Committee for the facilities which he was willing to give.

The following questions were put to the *Meteorological Committee*:—

1. Could accurate copies of the hourly tabulated values, taken from the traces of the various self-recording instruments of the Meteorological Committee, be procured? and on what terms?

2. Could accurate copies of certain portions of logs, relating to meteorological observations, or any other meteorological information in the possession of the Meteorological Committee, be procured? and on what terms?

The following reply has been received from the *Meteorological Committee*:—

Meteorological Department,
116 Victoria Street, London, S.W.
April 30, 1872.

SIR,—In reply to your inquiries, I am instructed to inform you that the Committee will be ready to afford to gentlemen recommended by the Council of any recognized Scientific Body facilities for obtaining accurate copies of MS. meteorological information which may be in their office.

1. Accurate copies of the hourly tabulated values taken from the traces of their self-recording instruments can be supplied.

2. Accurate copies of portions of logs relating to meteorological observations and of other meteorological information in the Meteorological Office can be supplied.

In every instance the cost of copying must be defrayed by the applicant, who, in the case of ships' logs, must state whether he prefers to have the observations corrected, or to receive the correction, and apply them himself. I am further to draw your attention to the fact that in the first Annual Report of this Committee, at page 11, it was stated that copies of information in the Meteorological Office could be supplied on the terms mentioned in the enclosed circular, which are identical with those above mentioned. I may say that several gentlemen have availed themselves of the opportunities offered.

I am &c.,
(Signed) ROBERT H. SCOTT,
Director.

Professor H. E. Roscoe.

[A circular accompanied Mr. Scott's reply, in which it is stated that in case of the publication of such information or of results wholly or in part from it, an acknowledgment of the source from which it has been obtained must be annexed.]

The Meteorological Committee were thanked in the name of the Committee for the facilities which they were willing to give.

The following questions were put to the *Kew Observatory Committee*:—

1. Might men of science be permitted to inspect the traces of the Kew self-recording magnetographs, and to take notes of them?

2. Could accurate copies of such traces be procured? and on what terms?
3. Could accurate copies of the hourly tabulated values from such traces be procured? and on what terms?

The following answer has been received :—

Kew Observatory, Richmond, Surrey, S.W.,
June 5, 1872.

Sir,—With reference to your letter of March 25th, addressed to the Kew Committee of the Royal Society, I am instructed to send you the following reply, which was adopted at their meeting of the 31st ult. :—

1. Resolved, that the Committee will be ready to afford facilities to men of science to inspect and take notes of the traces of the Self-recording Magnetographs; application to be forwarded in each case to the Secretary of the Committee, in order that arrangements may be made for the attendance of a duly authorized person.

2 & 3. The furnishing of unpublished results of tabulations not only involves considerable expense, but would materially disturb the current work of the Observatory. The Committee are therefore not prepared at present to supply copies of such results. They would, however, if necessary, gladly supply photographic copies of the instrumental traces at the cost of production, and they hope that this would meet the requirements of the case. In all three cases the cost would depend on the amount of time and labour required.

Your obedient Servant,
Robert H. Scott,
Hon. Sec.

Professor H. E. Roscoe, F.R.S.

The Kew Committee were thanked for their communication.

The following questions were put to the Director of the *Stonyhurst Observatory*:—

1. Might men of science be permitted to inspect the traces of the Stonyhurst self-recording magnetographs, and to take notes of them?
2. Could accurate copies of such traces be procured? and on what terms?

The following reply has been received from the Director of the *Stonyhurst Observatory*:—

Stonyhurst College, Blackburn.
April 3rd, 1872.

Dear Sir,—In answer to the two questions appended to the circular with which you favoured me this morning, I have little else to say than that I shall always be most happy to place at any gentleman's disposal the curves traced by the Stonyhurst instruments. I am at present working systematically at the tabulation of the magnetograph traces, and I hope to be able in time to publish the results, but this will not in the least interfere with any man of science recommended by your Committee taking any notes he may require.

Accurate copies of the distinct curves can easily be taken photographically; the assistant's time and the materials used will be the only things charged for. I could not undertake any thing that would deprive me of the aid of any of my assistants for any considerable time; but a fair sacrifice I am quite willing to make, and that is all I am sure you will expect.

Yours sincerely,
S. J. Perry.

Professor Roscoe.

The Director of the Stonyhurst Observatory was thanked by the Committee for the facilities which he was willing to give.

Subcommittee C.—On the question of Scientific Organization as regards Local Scientific Societies.

Your Committee, believing that much valuable scientific effort is being lost throughout the country for want of a system by which the labours of isolated workers can be brought forward, appointed a Subcommittee, with Sir Walter Elliot as Secretary, for the purpose of discussing and reporting whether some means can be taken for establishing closer relations than at present exist between Local Scientific Societies, which, as a rule, work independently each in their own circle, with little knowledge of what others are doing. It is thought that if such means can be adopted it may lead to something like unity of action amongst them, and to investigations productive of general results, as well as to the interchange of views and observations advantageous to Societies individually and to the cause of Science at large. The Subcommittee point out that this end may be accomplished in two ways :—

1. By the publication annually, in a collected form, of observations or discoveries possessing general interest.

2. By organizing a system of cooperation by personal or written communication, or both.

The Subcommittee also suggest that delegates from certain selected Societies, varying from year to year, together with representatives from such Societies as may find it convenient to depute them, should meet along with the British Association, and that to them should be submitted any general questions of combined action or inquiry ; and that the Councils of Local Scientific Societies should place in their hands such contributions made to the Societies during the year as they may think it desirable to publish in a common volume of Reports, the Court of Delegates being possibly assisted by the officers of Sections of the British Association acting along with them as a Committee of Selection. Your Committee think it right here to observe that all cost of publication and expenses incidental to such suggested Meetings must be defrayed by the Societies concerned.

After some preliminary discussions, the Subcommittee determined to communicate with as many of the Provincial Scientific Societies and Field Clubs as possible, explaining the objects for which the Subcommittee was appointed, and inviting them to consider the means by which the results of their operations could be made available to each other and to the advancement of science at large.

Circulars expressing the above-mentioned views were in June forwarded to ninety-four English, twenty-two Scotch, and eight Irish Local Scientific Societies. Replies cordially concurring in the plan have been received from the following Societies, several likewise engaging to send delegates to Brighton to deliberate further on its details :—

1. Bath Natural-History Society and Field Club.
2. Bristol Natural-History Society.
3. Eastbourne Natural-History Society.
4. Folkestone Natural-History Society.
5. Ludlow Natural-History Society.
6. Ludlow Field Club.
7. Lunesdale Naturalists' Field Club.
8. Maidstone and Mid Kent Natural-History and Philosophical Society.

9. Norfolk and Norwich Natural-History Society.
10. Tamworth Natural-History and Geological Society.
11. Tyneside Naturalists' Field Club.
12. Northumberland, Durham, and Newcastle Natural-History Society.
13. Whitby Literary and Philosophical Society.
14. Largs (Scotland) Field Naturalists' Society.

Acknowledgments have been sent by many more, promising that the subject shall receive their early attention.

The Subcommittee find that proposals of a similar character to those which they now put forward have previously been made by several Societies and private individuals who have favoured them with communications. These plans have, however, for one reason or other, proved abortive. Your Committee confidently hope that the Subcommittee on its reappointment may succeed in carrying out the objects aimed at.

In concluding what must inevitably be a very incomplete first Report, your Committee have only to request that they may be reappointed, and to express the hope that, if you see fit to renew their powers, they may be able in the coming year to make further progress.

Second Report of the Committee on Science-Lectures and Organization,—the Committee consisting of Prof. ROSCOE, *F.R.S.* (Secretary), Prof. W. G. ADAMS, *F.R.S.*, Prof. ANDREWS, *F.R.S.*, Prof. BALFOUR, *F.R.S.*, J. BAXENDELL, *F.R.A.S.*, F. J. BRAMWELL, *F.R.S.*, Prof. A. CRUM BROWN, *F.R.S.E.*, Mr. T. BUCHAN, Dr. CARPENTER, *F.R.S.*, Prof. CORE, WARREN DE LA RUE, *F.R.S.*, Prof. T. DYER, Sir WALTER ELLIOT, *F.L.S.*, Prof. M. FOSTER, *F.R.S.*, Prof. FLOWER, *F.R.S.*, Prof. G. C. FOSTER, *F.R.S.*, Prof. GEIKIE, *F.R.S.*, Dr. J. H. GLADSTONE, *F.R.S.*, Mr. GRIFFITH, Rev. R. HARLEY, *F.R.S.*, Dr. HIRST, *F.R.S.*, Dr. HOOKER, *F.R.S.*, Dr. HUGGINS, *F.R.S.*, Prof. HUXLEY, *F.R.S.*, Prof. FLEEMING JENKIN, *F.R.S.*, Dr. JOULE, *F.R.S.*, Col. A. LANE FOX, *F.G.S.*, Dr. LANKESTER, *F.R.S.*, J. N. LOCKYER, *F.R.S.*, Prof. CLERK MAXWELL, *F.R.S.*, D. MILNE-HOME, *F.R.S.E.*, Dr. O'CALLAGHAN, *LL.D.*, *D.C.L.*, Dr. ODLING, *F.R.S.*, Prof. RAMSAY, *F.R.S.*, W. SPOTTISWOODE, *F.R.S.*, Prof. BALFOUR STEWART, *F.R.S.*, H. T. STAINTON, *F.R.S.*, Prof. TAIT, *F.R.S.E.*, J. A. TINNÉ, *F.R.G.S.*, Dr. ALLEN THOMSON, *F.R.S.*, Sir WILLIAM THOMSON, *F.R.S.*, Prof. WYVILLE THOMSON, *F.R.S.*, Prof. TURNER, *F.R.S.E.*, Col. STRANGE, *F.R.S.*, Prof. A. W. WILLIAMSON, *F.R.S.*, G. V. VERNON, *F.R.A.S.*, *and* Dr. YOUNG.

THE report of this Committee will on the present occasion consist entirely of proceedings originating in the various Subcommittees, and which have likewise received the sanction of the full body. It will therefore be desirable to proceed without further delay to the business transacted by these Branch Committees.

Report of Subcommittee A *on Organization as regards Science-Lectures.* (Prof. Roscoe, Secretary.)

Subcommittee A on Science-Lectures have to report that a list has been printed, for private circulation only, of gentlemen who have kindly intimated to the Committee their readiness to undertake to aid the scheme by delivering lectures on scientific subjects on terms which are indicated. As certain Members of the Committee are also willing to deliver lectures, the names of the Committee are appended.

A short Circular, pointing out the aid which the Committee was thus willing to give, was forwarded (as a private communication) to about ninety Scientific Institutions throughout the country, with an intimation that a copy of the list of lecturers would be sent to any institution requiring assistance of the kind. Owing to the death of Mr. Askham, the late Clerk, the Secretary has been unable to learn the exact number of Institutions which have made application for the aid of the Committee; but, judging from the numerous letters which he has received on the subject, he believes that the action of the Committee in this matter has proved useful, and that the aid which has thus been afforded appears to be generally appreciated.

Report of Subcommittee B *on Organization as regards Meteorology.* (Dr. Balfour Stewart, Secretary.)

At a meeting of this Subcommittee, held at Albemarle Street, it was resolved, "That in the opinion of the Committee it is desirable that the individual observations in magnetism and meteorology, which at present exist, should, as much as possible, be accessible to all those men of science who wish to make use of them. They therefore request their Secretary (Dr. Stewart) to put himself into communication with the Directors of the following British and Colonial observational establishments, with a view of ascertaining,—

"(1) What unpublished individual observations in magnetism and meteorology they possess, specifying the most important.

"(2) On what terms, if any, will they consent to open them up to men of science desirous of obtaining copies of them.

"*British.*—The Meteorological Committee; the Greenwich Observatory; Sir E. Sabine (Magnetical Superintendent); the Scottish Meteorological Society; the Trinity House; the Hudson-Bay Company.

"*Colonial.*—The Observatory at Mauritius; Cape of Good Hope; Melbourne; Sydney; Toronto; Bombay; Calcutta; Madras."

The various replies to this communication are given at length in an appendix to this Report, and this Committee desire to express their thanks to the Directors of the various establishments, who, in sending their replies, have not only afforded much information regarding their unpublished observations, but have likewise shown their willingness to open up these observations to men of science as much as possible *.

* No communications have yet been addressed to foreign observatories.

It is requested that any observer into whose hands this Report may fall, and who may have information he is willing to communicate, will have the goodness to forward the same to Dr. Balfour Stewart, The Owens College, Manchester.

Report of Subcommittee C on Scientific Organization as regards Local Societies. (Sir WALTER ELLIOT, Secretary.)

The Subcommittee have given their best consideration to the instructions of the Committee, to report as to a plan for the systematic publication of the proceedings of local societies, with reference to the suggestion adopted at the Meeting held at Brighton, viz. to incorporate in an annual volume such papers as the societies considered worthy of reproduction, by means of a given number of additional copies struck off for the purpose. It was further added that the responsibility of selecting and publishing such papers as were offered should not be undertaken by the Association.

The chief difficulty to the elaboration of any such scheme is the financial one. It has been found that none of the Provincial Societies are in a position to contribute towards the cost, either of editing and publishing such papers, or even of furnishing additional copies printed of a uniform size, especially where, as often happens, they are accompanied by plates. It is also found that the local publications are so irregular in appearing, that it would be no easy matter to get a sufficient number together, to allow of their being brought out in a volume simultaneously. Moreover some of the leading societies, especially those of which the Transactions have attained some celebrity, object to the proposal, as tending to detract from the value of their own publications.

Besides the plan specially referred to them, the Subcommittee have considered other suggestions; for example, the issue of a quarterly or monthly magazine, containing the best papers of the various learned societies, not confined to those of the provinces, with the titles of the rest, and a brief outline of the proceedings of each. But this appears to go beyond the scope of the Subcommittee's deliberations, and to belong rather to an independent publishing speculation.

The Subcommittee, however, consider that a Handbook or List of Societies might be prepared annually, showing the names and addresses of the office-bearers of each, the day and place of meeting, and a list of the articles printed during the past year.

It is believed that by this means a closer intercourse would be induced; persons engaged in particular subjects of inquiry would be directed to sources of information bearing on their own investigations, and those engaged in similar pursuits would be led to assist each other.

An intercourse so commenced will, it may be hoped, lead to more intimate relations, and so bring about that larger cooperation and union which it is the object of the Committee to promote.

The Subcommittee believe that a Handbook of this description might be produced at a moderate cost. From the general approval of some plan of cooperation by the greater number of Provincial Societies, it is believed that they would readily purchase such an annual, the moderate cost of which would cover a part of the expenditure; and it is recommended that the Committee should apply to the Council for a small grant to cover the remainder.

At the Brighton Meeting, it was intimated by a member for the Society for Promoting Useful Knowledge, that if the Society resumed their publications they would probably aid in bringing out such a work.

H. E. ROSCOE, *Secretary to the Committee.*

Appendix to the Report of Subcommittee B.

The following replies have been received from the various observational institutions communicated with.

Meteorological Committee.

Meteorological Office,
116 Victoria Street, London, S.W.,
9th April, 1873.

DEAR SIR,

In compliance with the request contained in your letter of the 28th of February, I am directed by the Meteorological Committee to enclose, for the information of the Observational Subcommittee of the Science-Organization Committee of the British Association, a list of the principal unpublished materials in this office. It is understood that an answer to your second question has been already given in my letter to Dr. Roscoe of April 30, 1872. (See First Report.)

Yours faithfully,
ROBERT H. SCOTT, *Director.*

Balfour Stewart, Esq., LL.D.,
The Owens College, Manchester.

The tabulated information received from the Meteorological Committee will be found at the end of this Appendix.

Greenwich Observatory.

Royal Observatory, Greenwich, London, S.E.,
1873, March 3.

MY DEAR SIR,

In reply to your inquiry (on the part of the British Association) of March 1, as to the extent of unpublished observations of magnetism and meteorology preserved in this observatory :—

1. You will remark that the Greenwich Observations *in extenso* are in the library of the Philosophical Society of Manchester. Referring you to these volumes for the observations which are published, I will state the following as the deficiencies, generally.

2. The eye-observations of the three magnetometers (declination, horizontal force, vertical force) for every two hours, and sometimes more frequently, from 1841 to part of 1848, are printed in full. The indications derived from the photographic sheets for the salient points of the curves are printed in full from 1849 to 1867; after 1867 they are printed in detail only for the days of great disturbance, the means of the less disturbed days for useful purposes being printed. All the photographic curves exist, furnished with the base-lines and the time-scales, which make the records immediately available.

3. The means of numbers for all dips and measures of absolute force are printed; the individual readings are not printed.

4. The abstracts of meteorological observations are printed to an extent which you will best see in the Greenwich Observations. Few of the individual numbers are published; but the sheets of the two anemometers, the photographic sheets of the two thermometers (wet and dry), and of the barometer are all preserved and available.

5. As to the terms on which observations can be communicated. The omitted observations &c. can only be copied in manuscript *at this place*, either

by the Officers of the Observatory, or by persons engaged to come here for the purpose. When limited extracts are required, I will have them made here at once. When the extracts required are long, I will give every facility to other persons; the expense then ought to be borne, I think, by those who apply for them.

I am, my dear Sir,
Yours very truly,
G. B. Airy.

Professor Balfour Stewart.

Scottish Meteorological Society.

Scottish Meteorological Society,
General Post-Office Buildings,
Edinburgh, 13th May, 1873.

Dear Sir,

Your letter of 28th February last, enclosing the resolution of the Observational Subcommittee of the Science-Organization Committee of the British Association, dated 13th of the same month, was laid before the Council of this Society at their Meeting of 28th ult.

In reply, the Council have instructed me to state that the more important of the unpublished individual Observations in Meteorology which this Society possesses are the following:—

I. Regular daily observations made at the Society's Stations, beginning with January 1857. The Stations at which the observations have been and are made are given in the successive Numbers of the Society's Proceedings—the last issued of which I send by this post. The Stations are given on pp. 334–336 and 339–342. The nature of the observations will appear from the specimen of the Society's Schedule sent herewith. The hours of observation are 9 a.m. and 9 p.m. At Stykkisholm, in the N.W. of Iceland, the hours are 9 a.m., noon, and 9 p.m.

In addition to the regular daily observations of atmospheric pressure, temperature, humidity, wind (direction and force), rain, and cloud, observations are made at certain Stations on the temperature of the soil, of the sea, and of wells, and on ozone. The Stations at which such observations are made will be seen by consulting p. 329 of Journal sent.

II. Observations for elucidation of special questions:—

1. Daily curves showing for every ten minutes the pressure, temperature of dry and wet bulbs, and the rainfall from Nov. 1868 to Nov. 1872. The self-registering instruments with which these curves have been made were designed under the superintendence of the Marquis of Tweeddale, in connexion with the growth of agricultural products.

2. Observations, twelve times daily, at six Stations, on temperature of the soil (3, 12, 22 inches deep), together with observations of pressure, temperature, humidity, wind, rain, &c. during these four months, viz. July and October 1867, and January and April 1868.

3. Observations on temperature of drained and undrained hill pasture, and of drained and undrained arable land, at two Stations daily, from 1st October 1864 to 30th September 1865.

4. Daily maximum and minimum temperatures as shown by thermometers (not blackened) fully exposed to the sun and weather, at 4 feet over old grass, at eight Stations, from 1st April 1861 to 30th March 1862.

5. A large number of Term-day Observations (hourly) of temperature of sea (Hebrides), together with observations of pressure, temperature, humidity, &c. during 1858–63.

III. Old Registers:—

1. From July 1767 to November 1827, at Gordon Castle, giving pressure, temperature, rain, winds, &c. daily, and for shorter intervals during the same period at Sion House, Edinburgh, Selkirk, &c.

2. Daily register of pressure, temperature, and rain at Carbeth-Guthrie, from January 1817 to December 1859.

3. Daily register of pressure, temperature, humidity, rain, &c. at Dollar, from April 1836 to present time.

4. A number of other weather registers,—Edinburgh, 1820–36, Castle Newe, 1836–47, &c.

IV. Monthly Means and Sums:—

Of these may be specially mentioned the rainfall for individual months for nearly the whole of 290 Stations, discussed in the Papers on the Scottish Rainfall in Society's Journal.

As regards the unpublished meteorological information possessed by the Society, the Council have hitherto supplied copies of any portion of it to all meteorologists or other scientific men who have applied for it, free of charge. The Council will still be glad to continue to do so in so far as the very limited means at their disposal will enable them.

I am, yours faithfully,
ALEXANDER BUCHAN.

Professor Balfour Stewart.

Trinity House (received through Dr. J. H. Gladstone).

(Letter from Dr. Gladstone to Dr. Stewart.)

17 Pembridge Square, London,
28th April, 1873.

MY DEAR PROFESSOR STEWART,

I ought perhaps to have told you long before this what has been done in regard to the Trinity House. In accordance with the desire of the Science-Organization Committee, I put myself in communication with the Elder Brethren about their meteorological records, and received the reply of which I enclose a copy. You will see that in fully acceding to our request they asked me to come and judge for myself as to the value of their records. On the first convenient Tuesday I accordingly went to Tower Hill, and found that they possessed most voluminous returns from all the Lighthouses, giving the state of the barometer and thermometer, the direction and force of the wind, with description of fog, cloud, &c. every three hours, drawn out on tabulated forms, of which I send you one not filled up. At the Floating Lights a log-book is kept, in which is entered very much the same particulars, but not so frequently during the day, and not in a tabulated form.

Captain Nisbet, the Chairman of the Light Committee, spoke to me about the differences he had observed between the readings of different barometers and his endeavours to obtain the true correction for each. He has also tried to get "fog-marks" set up at the same distance from the different lighthouses; but at present there is no accepted definition as to where a "mist

ends and a "fog" begins. He would be thankful to us for any suggestion on these or other points.

From the enclosed "Regulations" you will see that every Light-keeper on being first appointed as a supernumerary has to learn the use of the meteorological instruments, and to obtain a certificate of competency in that and other duties.

Believe me,
Very truly yours,
J. H. GLADSTONE.

Professor Balfour Stewart, F.R.S.

(*Letter from Trinity House to Dr. Gladstone.*)

Trinity House, London, E.C.,
15th March, 1873.

DEAR SIR,

Sir Frederick Arrow having placed your note of the 10th instant, with its enclosed resolution of the Science-Organization Committee of the British Association, before the Board, I am directed to assure you of the pleasure it will be to the Elder Brethren to afford any facilities to men of science for the inspection of the Trinity House meteorological records that may be compatible with their official purpose; and I am to suggest that if you can make it convenient to attend here about half-past one o'clock on any Tuesday, the Light Committee will be happy to go fully into the matter with you.

I am, dear Sir,
Your most humble Servant,
(Signed) ROBIN ALLEN.

Dr. J. H. Gladstone, F.R.S.

Mauritius Observatory.

Observatory, Mauritius,
26th June, 1873.

MY DEAR STEWART,

I enclose a copy of my answers to your questions. We are to make a bold attempt to publish all our observations on the spot. The first step is to find out the cost, and the next to raise the funds. The local government will be applied to for a small annual grant. If we get the necessary assistance, there need be no delay, as the greater part of the material is ready, all the meteorological observations having been reduced.

Yours truly,
C. MELDRUM.

Answers to the Questions of the Subcommittee of the Science Organization.

(1) The unpublished observations, belonging either to the Mauritius Observatory or to the Meteorological Society of Mauritius, are as follows:—

(*a*) Observations of the principal meteorological elements taken since the 1st January, 1853, at 3½ and 9½ A.M. and P.M., and also for several years at noon.

Since the 1st January, 1872, the 3½ A.M. observations have been discontinued, and others taken at 6 A.M.

(*b*) Hourly meteorological observations on the 21st of each month, for a period of nineteen years and also during hurricane weather.

(c) Barographic curves since February 1872.

(d) An extensive collection of daily meteorological observations taken on board ships in the Indian Ocean for a period of twenty-five years. Since 1853 these observations have been tabulated in chronological order. They afford information respecting the atmospheric pressure and temperature, the direction and force of the wind, the state of the weather and sea &c., and amount to about 250,676 of twenty-four hours each.

(e) A separate collection of the details of the hurricanes, storms, and gales which have taken place in the Indian Ocean since 1847.

(f) A large number of daily synoptic weather-charts of the Indian Ocean for different periods since 1853, and charts showing the tracks of hurricanes.

(g) Observations of the absolute values and daily variations of the magnetic elements since February 1872.

(h) Sun-spot observations taken three or four times a week since 1869.

All these observations are valuable, but, considering the length of time and the locality, I think the meteorological observations are the most valuable.

(2) I have little doubt that the Observatory and the Meteorological Society would consent to open up the observations to men of science, on condition of their paying the expense of copying, and that they would, as far as possible, give copies gratis. The best and cheapest way in the end, however, would probably be to publish the observations *in extenso*, and to distribute copies of them. The Meteorological Society will do all in its power to accomplish this object.

C. MELDRUM.

Mauritius Observatory,
26th June, 1873.

Cape of Good Hope Observatory.

Royal Observatory, Cape of Good Hope,
1873, May 2.

MY DEAR SIR,

With respect to your letter requesting copies of magnetical observations which have been made here. Soon after I came here I hunted these records up and completed their reductions, but the observations have not received my final examination. I hope, however, to get them printed this year, when copies shall be at once forwarded to you. I am sorry, however, to say that the observations do not appear of great value. However, such as they are, you will soon have the results.

Believe me,
Yours very truly,
E. J. STONE.

Professor B. Stewart.

Melbourne Observatory.

Observatory, Melbourne,
May 20, 1873.

MY DEAR SIR,

I received your note and enclosure (resolution of the Observational Subcommittee of the B.A.) by last mail, and I am very glad to find a step has been taken in this most important direction. We shall be only too glad to make any arrangements we can to meet the end in view. I suppose, of course, there will be some general scheme adopted in which we can join.

In the mean time I enclose a memorandum showing how our observations in magnetism and meteorology now stand.

Since the beginning of 1872 we have published the *results* of meteorological observations at Melbourne, and those of the stations in a more condensed form; copies of this monthly Record are, I believe, sent to you every month, but I post another copy now in case I am mistaken. In this pamphlet you will see we give the results of our monthly observations for the absolute force of Terrestrial Magnetism.

The question, *how to make all these available to such men of science as may wish to make use of them*, is not easy to answer. Pentagraph or Photo copies of all the graphic records could be furnished; and MS. copies of such unpublished other observations could also be made to be deposited in any convenient place that the Committee of the B. A. may decide upon. This, or any other plan, I should be glad to adopt in order to render our work of use and available. I shall be glad to hear what the Subcommittee recommend or decide upon, and I shall do my best to fall in with its views.

Yours faithfully,
ROBERT J. ELLERY.

Balfour Stewart, Esq., Owens College, Manchester.

Magnetic Observations.

Between 1863 and the end of 1867 occasional absolute determinations were made with Lamont's instruments, which are unpublished; from December 1867 regular monthly absolute determinations were made with the Kew instruments, which are not published to the end of 1871; also the Magnetograph Curves are complete from December 1867, of which no results are published.

Meteorological Observations.

Barograph Curves complete from August 1, 1869—not published. Thermograph Curves complete from January 21, 1870— not published. Meteorological Observations for Melbourne and country stations, unpublished from January 1, 1863, to December 31, 1871. From January 1, 1872, results of Meteorological and absolute Magnetical Observations have been published monthly.

Sydney Observatory.

Sydney Observatory,
June 14, 1873.

DEAR SIR,

I am in receipt of your letter 6th of March, enclosing a resolution of the Subcommittee of the British Association.

I shall be glad to assist you in any way I can.

(1) Our magnetic observations are few; none were taken before Mr. Smalley's arrival in 1864, and, with the exception of a few determinations of variation and observations of dip at different parts of the colony, the rest were found at his death to be wanting in some essentials for their reduction.

At the present time the press of work, astronomical and meteorological (I have now more than forty stations), renders it impossible to do more than take the variation, but I hope in a few weeks to have a Declination Magnetograph at work.

I send you a short paper read before our Royal Society, in which I brought together all the available observations of variation at Sydney. So much may be of interest to science, but the curves of daily variation were only added for the use of our local surveyors.

I have a great mass of meteorological work, of which only monthly means have been printed. I will by next mail send you a complete set of our published results, from which you will be able to see what the means are derived from, and whether any of the individual observations are likely to be of service. Generally the country results are taken from one observation (per day) at 9 A.M., and at Sydney from three observations, 9 A.M., 3 P.M., and 9 P.M.

Of self-registering instruments we have an Anemometer at work since 1863, from which the direction of wind to sixteen points and the total velocity and mean daily force of wind have been published.

A Barograph at work since 1870: mean daily and highest and lowest readings published.

Two Pluviometers, one 65 and the other 7 feet above the ground: monthly amount from the one 65 feet high published. At work, one since 1867, the lower one since 1870.

Two Tide-gauges, one at Sydney since 1867, the other at Newcastle since 1870; no results published.

(2) I cannot state on what terms they could be opened up to men of science until I know what is wanted, for it may be only a fraction of what I have mentioned would be of any use. I may say that if fifteen or twenty sets, such as I will send you next month, will meet the want, I will be glad to send them; and if a portion only of the individual results are wanted, the Government here might perhaps grant money to print them if asked to do so by the British Association.

Yours faithfully,
H. C. RUSSELL,
Govt. Astronomer.

Balfour Stewart, Esq.,
The Owens College.

Toronto Observatory.

Magnetic Observatory, Toronto, Canada,
April 10, 1873.

DEAR SIR,

I am in receipt of your letter of March 6, enclosing copy of resolution of Subcommittee of Scientific Committee of British Association. The individual observations made at Toronto are as follows:—

Meteorological, from 1853 onwards.—Six daily observations of the ordinary elements at 6, 8 A.M., 2, 4, 10, 12 P.M.; continuous record of the wind; and during 1870–71 bihourly observations of the ordinary elements through the 24 hours, on three days in the week.

Of the above, the observations at 6 A.M., 2 P.M., 10 P.M., with the means of the *six* observations and the daily resultants of the wind for the whole day, have been always published in the 'Canadian Journal.'

Magnetism—Besides the regular monthly determinations of Declination, Dip, and Horizontal Force, six observations of the Differential Instruments have been taken daily since 1856, at the hours above named. Throughout the series, till recently, the disturbed observations have been separated and grouped in the manner adopted by Sir E. Sabine.

Various deductions both from the Meteorological and Magnetical Observa-

tions have been published in three volumes to 1862, and others subsequently in the Canadian journals. For reasons, chiefly financial, I have been hindered from utilizing as I would wish the results of the Toronto observations, by issuing regular and frequent publications of them. I am now, however, printing a volume which will give the principal results derived from the Toronto observations from their commencement to the end of 1871. This will be followed, I hope, by regular annual volumes giving results of observations from all the Canadian stations.

Though willing to regard it as a duty to do all in my power to meet the wishes of your Committee, I think that it would be better to postpone any decision on the second question in the resolution till the first of the volumes shall have been printed.

I am, dear Sir,
Very truly yours,
G. T. KINGSTON.

Balfour Stewart, Esq.

Bombay Observatory.

Kolàba Observatory, Bombay,
April 18, 1873.

DEAR SIR,

In reply to your letter of the 6th March, I subjoin a list of the unpublished observations in magnetism and meteorology at present in my possession.

Magnetic Observations.

Hourly readings of Magnetometers (Declination, Horizontal Force, and Vertical Force) from 1865·0 to 1873·0.

Photographic traces from Magnetographs:—

Declination from 1870·5 to 1873·0.
Horizontal Force from 1870·7 to 1873·0.
Vertical Force from 1872·1 to 1873·0.

Meteorological Observations.

Hourly readings of Barometer, Dry and Wet Thermometers, Ground Thermometers, and Rain-Gauges, estimation of wind and cloudiness, and description of weather phenomena, from 1865·0 to 1873·0.

Traces from Anemograph, direction and movement, from 1867·5 to 1873·0.

Photographic traces from Barograph, from 1871·9 to 1873·0.

Photographic traces from Thermograph (Dry and Wet Thermometers), from 1872·0 to 1873·0.

2. There is no present purpose of publishing the above *in detail*, but compilations of results of meteorological and *absolute* magnetical observations are published from time to time, the last volume issued including the years 1865 to 1870 and some discussion of special observations.

The absolute magnetical observations of Declination, Horizontal Force, and Dip are given in full detail.

3. The reduction and discussion of the whole body of observations, magnetical and meteorological, collected since 1846, is in progress at the Kolàba Observatory.

I should mention too that up to the year 1864 similar hourly observations to those described were printed, forming twenty-one large 4to volumes, and distributed amongst scientific bodies; but that little use seeming to have been made of them outside this observatory, the expense thus incurred, amounting to many thousands of pounds, represents, up to the present day, little more than so much waste. This statement I may observe reflects no discredit upon scientific men, seeing that the labour of reduction of such multitudinous observations is utterly beyond the power of any individual. But I think it justifies fully the course which the Government are now pursuing in devoting a part of the funds formerly granted for publication to the eliciting, by the agency of the observatory itself, of *some* scientific conclusions from the observations.

4. With reference to the Committee's second inquiry, I beg to inform you that I am permitted by Government to supply copies of observations on the same terms as those on which the Meteorological Committee of London furnish copies of their records, viz. on condition that the applicant pays the expense incurred in producing the copies. Any moderate demands that would not seriously interrupt the regular work of the observatory, I should gladly meet under this sanction.

I remain,
Yours sincerely,
CHARLES CHAMBERS.

Dr. Balfour Stewart, F.R.S.,
Secretary of the Observational Subcommittee
of the Organization Committee of the
British Association.

Calcutta Observatory.

Meteorological Office, Calcutta,
May 26, 1873.

DEAR SIR,

I understand, from the Report of the Proceedings of the Observational Subcommittee of the Science-Organization Committee of the British Association, that the Committee desires information what original meteorological registers exist in this office which have not been published in detail. I append a list, but would remark that many of the registers contain some entries which are evidently erroneous. Copies of any of these that I consider trustworthy can be furnished to the British Association for the cost of copying.

It obviously depends on the nature of the inquirer's object which of these registers he would hold to be most important. In some respects I am inclined to regard Darjeeling as the most important, since it affords, what is rare in most parts of the world, a register (continuous for nearly six years) of a station at an elevation of about 7000 feet. Goalparah, at the embouchure of the Assam valley, is interesting for comparison with Darjeeling.

The most complete and detailed register extant in Bengal is that of the Calcutta Observatory at the Surveyor-General's Office, which consists of hourly observations recorded continuously since 1853. These are very valuable, but are not equal to those of Bombay or Madras.

Believe me, dear Sir,
Yours faithfully,
HENRY F. BLANFORD.

Balfour Stewart, Esq.,
Secretary to Observational Subcommittee,
British Association.

Port Blair	From October 1867 to December 1872.			
Vizagapatam	„ January 1870	„	„	
Akyab	„ May 1866	„	„	wanting 1–13 June, 1867.
False Point.........	„ January 1866	„	„	
Cuttack	„ June 1867	„	„	
Saugor Island......	„ January 1865	„	„	
Chittagong	„ June 1867	„	„	
Jessore...............	„ Dec. 1868	„	„	
Dacca	„ January 1868	„	„	
Cachar........	„ July 1869	„	„	
Hazaree haugh ...	„ Nov. 16 1868	„	„	
Berhampore	„ Nov. 1868	„	„	
Gya	„ May to Dec. 1869 and January to December 1872.			
Patna	„ Dec. 1868 to December 1872.			
Monghyr.....	„ Dec. 1868	„	„	
Darjeeling	„ July 1867	„	„	
Goalparah	„ January 1869	„	„	
Shillong	„ June 1869	„	„	
Maldoh	„ August 1869	„	„	
Baucoovah .. .	„ August 1869 to September 1872,			wanting February, March, and July 1869.
Midnapore ...	„ August 1869 to December 1872,			wanting Jan. and Mar. 1870.
Rajshahye .. .	„ August 1869 to September 1871.			
Tipperah	„ Feb. 1869 to December 1872,			wanting April 1872.
Soovy	„ Aug. 1867	„	„	wanting July and Sept. 1872.
Fureedpore	„ January 1869	„	„	
Buxa	„ January 1869	„	„	wanting May and Oct. 1870 and Oct. 1872.
Seebsaugor ...	„ January 1869	„	„	wanting Oct. 1872.
Gowhalty	„ January 1869	„	„	wanting May 1870 and Nov. 1872.
Pooree	„ August 1867	„	1868.	
Chuprah	„ August 1867 to April		1869.	
Rajmahal . ..	„ August 1867 to January		1869.	
Nowgony	„ January 1869 to April		1870,	wanting Feb. and April 1869.

Hudson's Bay Company.

Hudson's Bay House,
1 Lime Street, London, E.C.,
March 7, 1873.

Sir,

I have to acknowledge your letter of the 5th inst., and to state that the Hudson's Bay Company have no unpublished information of the nature to which you refer.

I think if you apply to the Bishop of Rupert's Land, Manitoba, you will likely obtain material assistance in the matter.

I am, Sir,
Your obedient Servant,
W. Armit,
Secretary.

Balfour Stewart, Esq.,
Manchester.

*

List of the *principal unpublished* materials in the Meteorological Office.

TABLE I.—Marine.

Ocean.		District discussed.	Nature of work done.	Remarks.
North Atlantic	(1)	Lat. 0° to 60°	Wind data in 5° squares. Direction and force for each month. Maury's observations combined with those of Meteorological Office.	This work was done by Admiral FitzRoy; and the middle months of each quarter were published in 1859*.
„	(2)	„ 40 to 60	Sea-temperatures and currents, extracted from Meteorological-Office logs, in 5° squares.	Used by Admiralty for Physical Charts.
„	(3)	„ 0 to 60	Observations of barometer, thermometer, wind, and weather, specific gravity, &c., grouped in Data-books for each 5° square.	Collected by Admiral FitzRoy; scanty.
„	(4)	„ 0 to 60	*The observations contained in item (1) from Meteorological-Office logs only, grouped in a tabular form.	Printed, but not published.
„	(5)	„ 0 to 20	All meteorological observations grouped in 1° squares for each month.	Collected &c. by Meteorological Committee.
South Atlantic	(6)	„ 0 to 10	„ „ „	„ „
„	(7)	„ 0 to 60	Wind data, corresponding to item (1)	Collected &c. by Admiral FitzRoy.
„	(8)	„ 0 to 60	Observations of barometer &c., corresponding to item (3)..........	Collected &c. by Admiral FitzRoy; [scanty.
„	(9)	„ 0 to 60	Currents, grouped in a Table of 5° squares for each month.	
North Pacific	(10)	Whole surface	Meteorological data. Three equidistant observations daily, grouped in 5° squares for each month, with totals and averages of observations.	
South Pacific	(11)	„	„ „ „	A small portion (Cape Horn and west coast of South America) published in No. 11.
Indian Ocean	(12)	„	Observations as in item (4)........................	Collected by Admiral FitzRoy.
Mediterranean and other inland seas.	(13)	„	„ „	„ „
All Oceans	(14)	....	Collection of remarkable passages, gales, ice, &c., from Meteorological Registers.	Were once printed, but not published.
„	(15)	....	Collections of currents, from Meteorological-Office and Admiralty logs (eight MS. vols.).	By Admiral FitzRoy.
Antarctic	(16)	Lat. 60 to 78 S.	Observations made on board H.M.S. 'Erebus,' 'Terror,' and 'Pagoda.'	Nearly ready for publication.

* N.B.—This statement does not take into account the undigested observations not yet extracted from the Registers.

TABLE II.—British Islands.

Station.	Nature of work done.	Date.	Remarks.
7 Self-recording Observatories:—			
Aberdeen	Hourly tabulations of barometer, thermometer, and wind and rainfall	Since 1868. Since January 1871.	5-*day* means of barometer and thermometer, and continuous curves, published in Quarterly Weather Report.
Armagh			
Falmouth			
Glasgow			
Kew			
Stonyhurst			
Valencia			
7 Anemograph Stations:—			
Alnwick	Hourly tabulations of direction and velocity.	From March 1870.	None yet published, except Orkney for six years ending 1868.
Halifax		,, January 1871.	
Holyhead		,, August 1869.	
* Kensington		,, September 1869.	
Orkney		,, July 1869.	
Seaham		,, November 1872.	
Yarmouth		,, September 1869.	
Oban	Monthly abstracts made by Captain Thomas, R.N., during Admiralty Survey.	1858–1865	Some of these means were published by the Scottish Meteorological Society.
Miscellaneous	Observations received monthly from about forty stations distributed over the British Isles, and specified in Annual Reports of the Office. These stations are in addition to the *telegraphic* reporting stations, and commence at dates	subsequent to 1867.	None *yet* published; but the observations are to some extent utilized in writing the Chronicle of the Quarterly Weather Report. If negotiations which have been commenced by the Registrar General for the preparation of his Reports by the Meteorological Office come to the conclusion indicated, results from these observations will be published systematically.

* Two years only.

Table III.—Foreign and Colonial.

Station.	Nature of observations.	Date.	Remarks.
Angra do Heroismo (Azores), Funchal (Madeira).	One observation daily. Readings corrected and reduced in millimetres and Centigrade.	Since January 1870.	Means from these stations are published in Portugal.
Apia. Samoa (Navigators' Islands).	Meteorological observations unreduced. One observation daily.	Twenty months, not continuous, in 1862–1865.	By J. C. Williams, Consul.
Ascension	Hourly observations with monthly means of barometer and thermometer. Anemometrical observations and reductions.	October 1863 to October 1865.	By Lieutenant Rokeby.
Bangkok (Siam)	Two observations daily, with monthly means.	January to December 1858	By Dr. Campbell, attached to H.M. Consulate.
	Three ,, ,, no means deduced ...	1859–1861, 1863–1867	There are several interruptions in the series.
Bermuda	Anemometrical observations (not tabulated).	Since 1868 ...	Observations for previous years, so far as reliable, now in the press.
Ceylon, Point de Galle ...	Two observations daily, and monthly means	From January 1869, continuing.	By D. Blyth, Master Attendant.
Corfu	Mean maximum and minimum readings of barometer and thermometer.	Oct. 1859 to Sept. 1860.	
Fiji	Monthly abstracts of barometer, thermometer, and rain.	Jan. 1865 to June 1867	By Mr. Binner, Wesleyan Training Master.
Gibraltar	Two observations daily, with monthly means.	Since June 1870, continuing	The original observations are supplied to Army Medical Department.
Lighthouses:—			
Cape Pembroke (Falklands).	Uncorrected observations of barometer, thermometer, wind, &c., made several times daily.	From July 1869, continuing.	
* King George's Sound (2)	...	July 1861 to Dec. 1869.	Not very trustworthy.
Abaco (Bahamas) ...	...	March 1858 ,, June 1860, July 1871, continuing.	
Cay Sal (Bahamas) ...	...	March 1858 to June 1860, July 1871, continuing.	
Great Isaacs (Bahamas)	...	Aug. 1859 to Jan. 1860.	
Gun Cay ,,	...	Jan. 1858 ,, July 1859	
Inagua ,,	...	July 1871 ,, June 1872.	
Sombrero ,,	...	Sept. 1867, continuing.	
Natal (Maritzburg)	Complete observations three times daily; monthly averages are made out.	Jan. 1860 to Feb. 1866	By Dr. R. J. Mann. January 1858 to March 1859 published in fifth Number of Meteorological Papers.
Tahiti	Means of observations taken four times daily. The measures are French.	May 1855 to June 1860.	Extracts from the 'Messager de Tahiti.'
Trinidad	Observations twice daily of barometer, thermometer, wind, &c. Monthly means are deduced	Feb. 1862 to June 1864.	Mr. Crüger, the observer, published a pamphlet embodying some of the results.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

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MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Address by Prof. H. J. S. Smith, *M.A.*, *F.R.S.*, *President of the Section.*

For several years past it has been the custom for the President of this Section, as of the other Sections of the Association, to open its proceedings with a brief address. I am not willing upon this occasion to deviate from the precedent set by my predecessors, although I feel that the task presents peculiar difficulties to one who is by profession a pure mathematician, and who in other branches of science can only aspire to be regarded as an amateur.

But although I thus confess myself a specialist, and a specialist it may be said of a narrow kind, I shall not venture, in the few remarks which I now propose to make, to indulge my own specialty too far.

I am well aware that we are certain in this Section to have a sufficient number of communications which of necessity assume a special and even an abstruse character, and which, whatever pains may be taken to give them clearness, and however valuable may be the results to which they lead, are nevertheless extremely difficult to follow, not only for a popular audience, but even for men of science whose attention has not been specially and recently directed to the subject under discussion. I should think it, therefore, almost unfair to the Section if, at the very commencement of its proceedings, I were to attempt to direct its attention in any exclusive manner to the subject which I confess, if I were left to myself, I should most naturally have chosen—the history of the advances that have been made during the last ten or twenty years in mathematical science. Instead, therefore, of adventuring myself on this difficult course, which, however, I strongly recommend to some successor of mine less scrupulous than myself, I propose, though at the risk of repeating what has been better said by others before me, to offer some general considerations which may have a more equal interest for all those who take part in the proceedings of this Section, and which appear to me at the present time to be more than usually deserving of the notice of those who desire to promote the growth of the scientific spirit in this country. I intend therefore, while confining myself as strictly as I can to the range of subjects belonging to this Section, to point out out one or two, among many, of the ways in which sectional meetings such as ours may contribute to the advancement of Science.

We all know that Section A of the British Association is the Section of Mathematics and Physics; and I dare say that many of us have often thought how astonishingly vast is the range of subjects which we slur over, rather than sum up, in this brief designation. We include the most abstract speculations of pure mathematics, and we come down to the most concrete of all phenomena, the most every-day of all experiences. I think I have heard in this Section a discussion on spaces of five dimensions; and we know that one of our Committees, a Committee

which is of long standing, and which has done much useful work, reports to us annually on the Rainfall of the British Isles. Thus our wide range covers the mathematics of number and quantity in their most abstract forms, the mathematics of space, of time, of matter, of motion, and of force, the many sciences which we comprehend under the name of astronomy, the theories of sound, of light, heat, electricity, and, besides the whole physics of our earth, sea, and atmosphere, the theory of earthquakes, the theory of tides, the theory of all movements of the air, from the lightest ripple that affects the barometer up to a cyclone. As I have already said, it is impossible that communications on all these subjects should be interesting, or indeed intelligible, to all our members; and notwithstanding the pains taken by the Committee and by the Secretaries to classify the communications offered to us, and to place upon the same days those of which the subjects are cognate to one another, we cannot doubt that the disparateness of the material which comes before us in this Section is a source of serious inconvenience to many members of the Association. Occasionally, too, the pressure upon our time is very great, and we are obliged to hurry over the discussions on communications of great importance, the number of papers submitted to us being, of course, in a direct proportion to the number of the subjects included in our programme. It has again and again been proposed to remedy these admitted evils by dividing the Section, or at least by resolving it into one or more subsections. But I confess that I am one of those who have never regretted that this proposal has not commended itself to the Association, or indeed to the section itself. I have always felt that by so subdividing ourselves we should run the risk of losing one or two great advantages which we at present possess; and I will briefly state what, in my judgment, these advantages are.

I do not wish to undervalue the use to a scientific man of listening to and taking part in discussions on subjects which lie wholly in the direction in which his own mind has been working. But I think, nevertheless, that most men who have attended a Meeting of this Association, if asked what they have chiefly gained by it, would answer, in the first place, that they have had opportunities of forming or of renewing those acquaintances or intimacies with other scientific men which, to most men engaged in scientific pursuits, are an indispensable condition of successful work; and in the second place, that while they may have heard but little relating to their own immediate line of inquiry which they might not as easily have found in journals or transactions elsewhere, they have learned much which might otherwise have never come to their knowledge of what is going on in other directions of scientific inquiry, and that they have carried away many new conceptions, many fruitful germs of thought, caught perhaps from a discussion turning upon questions apparently very remote from their own pursuits. An object just perceptible on a distant horizon is sometimes better descried by a careless sideward glance than by straining the sight directly at it; and so capricious a gift is the inventive faculty of the human mind, that the clue to the mystery hid beneath some complicated system of facts will sometimes elude the most patient and systematically conducted search, and yet will reveal itself all of a sudden upon some casual suggestion arising in connexion with an apparently remote subject. I believe that the mixed character and wide range of our discussions has been most favourable to such happy accidents. But even apart from these, if the fusion in this Section of so many various branches of human knowledge tends in some degree to keep before our minds the essential oneness of Science, it does us a good service. There can be no question that the increasing specialization of the sciences, which appears to be inevitable at the present time, does nevertheless constitute one great source of danger for the future progress of human knowledge. This specialization is inevitable, because the further the boundaries of knowledge are extended in any direction, the more laborious and time-absorbing a process does it become to travel to the frontier; and thus the mind has neither time nor energy to spare for the purpose of acquainting itself with regions that lie far away from the track over which it is forced to travel. And yet the disadvantages of excessive specialization are no less evident, because in natural philosophy, as indeed in all things on which the mind of man can be employed, a certain wideness of view is essential to the achievement of any great result, or to the discovery of any thing really new. The

twofold caution so often given by Lord Bacon against over-generalization on the one hand, and against over-specialization on the other, is still as deserving as ever of the attention of mankind. But in our time, when vague generalities and empty metaphysics have been beaten once, and we may hope for ever, out of the domain of exact science, there can be but little doubt on which side the danger of the natural philosopher at present lies. And perhaps in our Section, as at present constituted, there is a freer and fresher air; we are, perhaps, a less inadequate representation of "that greater and common world" of which Lord Bacon speaks, than if we were subdivided into as many parts as we include, I will not say sciences, but groups of sciences. Perhaps there is something in the very diversity and multiplicity of the subjects which come before us which may serve to remind us of the complexity of the problems of science, of the diversity and multiplicity of nature.

On the other hand, it is not, as it seems to me, difficult to assign the nature of the unity which underlies the diversity of our subjects, and which justifies to a very great extent the juxtaposition of them in our Section. That unity consists not so much in the nature of the subjects themselves as in the nature of the methods by which they are treated. A mathematician at least (and it is as a mathematician I have the privilege of addressing you) may be excused for contending that the bond of union among the physical sciences is the mathematical spirit and the mathematical method which pervades them. As has been said with profound truth by one of my predecessors in this chair, our knowledge of nature, as it advances, continuously resolves differences of quality into differences of quantity. All exact reasoning (indeed all reasoning) about quantity is mathematical reasoning; and thus, as our knowledge increases, that portion of it which becomes mathematical increases at a still more rapid rate. Of all the great subjects which belong to the province of this Section, take that which at first sight is the least within the domain of mathematics; I mean meteorology Yet the part which mathematics bears in meteorology increases every year, and seems destined to increase. Not only is the theory of the simplest instruments of meteorology essentially mathematical, but the discussion of the observations—upon which, be it remembered, depends the hopes which are already entertained with increasing confidence of reducing the most variable and complex of all known phenomena to exact laws—is a problem which not only belongs wholly to mathematics, but which taxes to the utmost the resources of the mathematics which we now possess. So intimate is the union between mathematics and physics that probably by far the larger part of the accessions to our mathematical knowledge have been obtained by the efforts of mathematicians to solve the problems set to them by experiment, and to create "for each successive class of phenomena a new calculus or a new geometry, as the case might be, which might prove not wholly inadequate to the subtlety of nature." Sometimes, indeed, the mathematician has been before the physicist; and it has happened that when some great and new question has occurred to the experimentalist or the observer, he has found in the armoury of the mathematician the weapons which he has needed ready made to his hand. But much oftener the questions proposed by the physicist have transcended the utmost powers of the mathematics of the time, and a fresh mathematical creation has been needed to supply the logical instrument requisite to interpret the new enigma. Perhaps I may be allowed to mention an example of each of these two ways in which mathematical and physical discovery have acted and reacted on each other. I purposely choose examples which are well known, and belong, the one to the oldest, the other to the latest times of scientific history.

The early Greek geometers, considerably before the time of Euclid, applied themselves to the study of the various curve lines in which a conical figure may be cut by a plane—curve lines to which they gave the name, never since forgotten, of conic sections. It is difficult to imagine that any problem ever had more completely the character of a "problem of mere curiosity" than this problem of the conic sections must have had in those earlier times. Not a single natural phenomenon which in the state of science at that time could have been intelligently observed was likely to require for its explanation a knowledge of the nature of these curves. Still less can any application to the arts have seemed possible; a nation which did not even use the arch were not likely to use the ellipse in any

work of construction. The difficulties of the inquiry, the pleasure of grappling with the unknown, the love of abstract truth, can alone have furnished the charm which attracted some of the most powerful minds in antiquity to this research. If Euclid and Apollonius had been told by any of their contemporaries that they were giving a wholly wrong direction to their energies, and that, instead of dealing with the problems presented to them by nature, they were applying their minds to inquiries which not only were of no use, but which never could come to be of any use, I do not know what answer they could have given which might not now be given with equal or even greater justice to the similar reproaches which it is not uncommon to address to those mathematicians of our own day who study quantics of n indeterminates, curves of the nth order, and, it may be, spaces of n dimensions. And not only so, but for pretty near two thousand years the experience of mankind would have justified the objection; for there is no record that during that long period which intervened between the first invention of the conic sections and the time of Galileo and Kepler the knowledge of these curves possessed by geometers was of the slightest use to natural science. And yet, when the fulness of time was come, these seeds of knowledge, that had waited so long, bore plentiful fruit in the discoveries of Kepler. If we may use the great names of Kepler and Newton to signify stages in the progress of human discovery, it is not too much to say that without the treatises of the Greek geometers on the conic sections there could have been no Kepler, without Kepler no Newton, and without Newton no science in our modern sense of the term, or at least no such conception of nature as now lies at the basis of all our science, of nature as subject in its smallest as well as in its greatest phenomena, to exact quantitative relations, and to definite numerical laws.

This is an old story; but it has always seemed to me to convey a lesson, occasionally needed even in our own time, against a species of scientific utilitarianism which urges the scientific man to devote himself to the less abstract parts of science as being more likely to bear immediate fruit in the augmentation of our knowledge of the world without. I admit, however, that the ultimate good fortune of the Greek geometers can hardly be expected by all the abstract speculations which, in the form of mathematical memoirs, crowd the transactions of the learned societies; and I would venture to add that, on the part of the mathematician, there is room for the exercise of good sense and, I would almost say, of a kind of tact, in the selection of those branches of mathematical inquiry which are likely to be conducive to the advancement of his own or any other science.

I pass to my second example, of which I may treat very briefly. In the course of the present year a treatise on electricity has been published by Professor Maxwell, giving a complete account of the mathematical theory of that science, as we owe it to the labours of a long series of distinguished men, beginning with Coulomb, and ending with our own contemporaries, including Professor Maxwell himself. No mathematician can turn over the pages of these volumes without very speedily convincing himself that they contain the first outlines (and something more than the first outlines) of a theory which has already added largely to the methods and resources of pure mathematics, and which may one day render to that abstract science services no less than those which it owes to astronomy. For electricity now, like astronomy of old, has placed before the mathematician an entirely new set of questions, requiring the creation of entirely new methods for their solution, while the great practical importance of telegraphy has enabled the methods of electrical measurement to be rapidly perfected to an extent which renders their accuracy comparable to that of astronomical observations; and this makes it possible to bring the most abstract deductions of theory at every moment to the test of fact. It must be considered fortunate for the mathematicians that such a vast field of research in the application of mathematics to physical inquiries should be thrown open to them at the very time when the scientific interest in the old mathematical astronomy has for the moment flagged, and when the very name of physical astronomy, so long appropriated to the mathematical development of the theory of gravitation, appears likely to be handed over to that wonderful series of discoveries which have already taught us so much concerning the physical constitution of the heavenly bodies themselves.

Having now stated, from the point of view of a mathematician, the reasons which appear to me to justify the existence of so composite an institution as Section A, and the advantages which that very compositeness sometimes brings to those who attend its meetings, I wish to refer very briefly to certain definite services which this Section has rendered and may yet render to Science. The improvement and extension of scientific education is to many of us one of the most urgent questions of the day; and the British Association has already exerted itself more than once to press the question on the public attention. Perhaps the time has arrived when some further efforts of the same kind may be desirable. Without a rightly organized scientific education we cannot hope to maintain our supply of scientific men, since the increasing complexity and difficulty of science renders it more and more difficult for untaught men, by mere power of genius, to force their way to the front. Every improvement, therefore, which tends to render scientific knowledge more accessible to the learner, is a real step towards the advancement of science, because it tends to increase the number of well qualified workers in science.

For some years past this Section has appointed a committee to aid the improvement of geometrical teaching in this country. The Report of this committee will be laid before the Section in due course; and without anticipating any discussion that may arise on that Report, I think I may say that it will show that we have advanced at least one step in the direction of an important and long-needed reform. The action of this Section led to the formation of an Association for the improvement of geometrical teaching; and the members of that Association have now completed the first part of their work. They seem to me, and to other judges much more competent than myself, to have been guided by a sound judgment in the execution of their difficult task, and to have held, not unsuccessfully, a middle course between the views of the innovators who would uphold the absolute monarchy of Euclid, or, more properly, of Euclid as edited by Simson, and the radicals who would dethrone him altogether. One thing at least they have not forgotten, that geometry is nothing if it be not rigorous, and that the whole educational value of the study is lost if strictness of demonstration be trifled with. The methods of Euclid are, by almost universal consent, unexceptional in point of rigour. Of this perfect rigorousness his doctrine of parallels, and his doctrine of proportion, are perhaps the most striking examples. That Euclid's treatment of the doctrine of parallels is an example of perfect rigorousness, is an assertion which sounds almost paradoxical, but which I nevertheless believe to be true. Euclid has based his theory on an axiom (in the Greek text it is one of the postulates; but the difference for our purpose is immaterial) which, it may be safely said, no unprejudiced mind has ever accepted as self-evident. And this unaxiomatic axiom Euclid has chosen to state, without wrapping it up or disguising it, not, for example, in the plausible form in which it has been stated by Playfair, but in its crudest shape, as if to warn his reader that a great assumption was being made. This perfect honesty of logic, this refusal to varnish over a weak point, has had its reward; for it is one of the triumphs of modern geometry to have shown that the eleventh axiom is so far from being an axiom, in the sense which we usually attach to the word, that we cannot at this moment be sure whether it is absolutely and rigorously true, or whether it is a very close approximation to the truth. Two of those whose labours have thrown much light on this difficult theory are at present at this Meeting—Prof. Cayley, and a distinguished German mathematician, Dr. Felix Klein; and I am sure of their adherence when I say that the sagacity and insight of the old geometer are only put in a clearer light by the success which has attended the attempt to construct a system of geometry, consistent with itself, and not contradicted by experience, upon the assumption of the falsehood of Euclid's eleventh axiom.

Again, the doctrine of proportion, as laid down in the fifth book of Euclid, is probably still unsurpassed as a masterpiece of exact reasoning, although the cumbrousness of the forms of expression which were adopted in the old geometry has led to the total exclusion of this part of the elements from the ordinary course of geometrical education. A zealous defender of Euclid might add with truth that the gap thus created in the elementary teaching of mathematics has never been adequately supplied.

But after all has been said that can be said in praise of Euclid, the fact remains that the form in which the work is composed renders it unsuitable for the earlier stages of education. Euclid wrote for men, whereas his work has been used for children; and it is surely no disparagement to the great geometer to suppose that after more than 2000 years the experience of generations of teachers can suggest changes which may make his 'Elements,' I will not say more perfect as a piece of geometry, but more easy for very young minds to follow. The difficulty of a book or subject is indeed not in itself a fatal objection to its use in education; for to learn how to overcome difficulties is one great part of education. Geometry is hard, just as Greek is hard; and one reason why Geometry and Greek are such excellent educational subjects is precisely that they are hard. But in a world in which there is so much to learn, we must learn every thing in the easiest way in which it can be learnt; and after we have smoothed the way to the utmost of our power there is sure to be enough of difficulty left. I regard the question of some reform in the teaching of elementary geometry as so completely settled by a great concurrence of opinion on the part of the most competent judges, that I should hardly have thought it necessary to direct the attention of the Section to it, if it were not for the following reasons:—

First, that the old system of geometrical instruction still remains (with but few exceptions) paramount in our schools, colleges, and universities, and must remain so until a very great *consensus* of opinion is obtained in favour of some one definite text-book. It appears to me, therefore, that the duty will eventually devolve upon this Section of the British Association, of reporting on the attempts that have been made to frame an improved system of geometrical education; and if it should be found that these attempts have been at last successful, I think that the British Association would lend the whole weight of its authority to the proposed change. I am far from suggesting that any such decision should be made immediately. The work undertaken by the Association for the improvement of geometrical teaching is still far from complete; and even when it is complete it must be left to hold its own against the criticism of all comers before it can acquire such an amount of public confidence as would justify us in recommending its adoption by the great teaching and examining bodies of the country.

Secondly, I have thought it right to remind the Section of the part it has taken with reference to the reform of geometrical teaching, because it appears to me that a task, at once of less difficulty and of more immediate importance, might now be undertaken by it with great advantage. There is at the present moment a very general agreement that a certain amount of natural science ought to be introduced into school education; and many schools of the country have already made most laudable efforts in this direction. As far as I can judge, there is further a general agreement that a good school course of natural science ought to include some part or parts of physics, of chemistry, and of biology; but I think it will be found that while the courses of chemistry given at our best schools are in the main identical, there is the greatest diversity of opinion as to the parts of physics and of biology which should be selected as suitable for a school education, and a still greater diversity of opinion as to the methods which should be pursued in teaching them. Under these circumstances it is not surprising to find that the masters of those schools into which natural science has hardly as yet found its way (and some of the largest and most important schools in the country are in this class) are doubtful as to the course which they should take, and, from not knowing precisely what they should do, have not as yet made up their minds to do any thing of importance. There can be no doubt that the masters of such schools would be glad on these points to be guided by the opinion of scientific men; and I cannot help thinking that this opinion would be more unanimous than is commonly supposed, and, further, that no public body would be so likely to elicit an expression of it as a Committee appointed by the British Association. I believe that, if such an expression of the opinion of scientific men were once obtained, it would not only tend to give a right direction to the study of natural science in schools, but might also have the effect of inducing the public generally to take a higher and more truthful view of the objects which it is sought to attain by introducing natural science as an essential element into all courses of education. All knowledge of natural science that is im-

parted to a boy, is, or may be, useful to him in the business of his after life; but the claim of natural science to a place in education cannot be rested upon its practical usefulness only. The great object of education is to expand and to train the mental faculties; and it is because we believe that the study of natural science is eminently fitted to further these two objects, that we urge its introduction into school studies. Science expands the minds of the young, because it puts before them great and ennobling objects of contemplation; many of its truths are such as a child can understand, and yet such that, while in a measure he understands them, he is made to feel something of the greatness, something of the sublime regularity, and of the impenetrable mystery of the world in which he is placed. But science also trains the growing faculties; for science proposes to itself truth as its only object, and it presents the most varied and at the same time the most splendid examples of the different mental processes which lead to the attainment of truth, and which make up what we call reasoning. In science error is always possible, often close at hand; and the constant necessity for being on our guard against it is one important part of the education which science supplies. But in science sophistry is impossible; science knows no love of paradox; science has no skill to make the worse appear the better reason; science visits with a not long-deferred exposure all our fondness for preconceived opinions, all our partiality for views that we have ourselves maintained, and thus teaches the two best lessons that can well be taught—on the one hand the love of truth, and on the other sobriety and watchfulness in the use of the understanding.

In accordance with these views I am disposed to insist very strongly on the importance of assigning to physics (that is to say, to those subjects which we discuss in this Section) a very prominent place in education. From the great sciences of observation, such as botany, or zoology, or geology, the young student learns to observe, or, more simply, to use his eyes; he gets that education of the senses which is after all so important, and which a purely grammatical and literary education so wholly fails to give. From chemistry he learns, above all things, the art of experimenting, and experimenting for himself. But from physics, better as it seems to me than from any part of science, he may learn to reason with consecutiveness and precision from the data supplied by the immediate observation of natural phenomena. I hope we shall see the time when each successive portion of mathematical knowledge acquired by the pupil will be made immediately available for his instruction in physics, and when every thing that he learns in the physical laboratory will be made the subject of mathematical reasoning and calculation. In some few schools I believe that this is already the case; and I think we may hope well for the future both of mathematics and physics in this country when the practice becomes universal. In one respect the time is favourable for such a revolution in the mode of teaching physical science. During the past few years a number of text-books have been made available to the learner which far surpass any thing that was at the disposal of former generations of pupils, and which are probably as completely satisfactory as the present state of science will admit. It is pleasant to record that these text-books are the work of distinguished men who have always taken a prominent part in the proceedings of this Section. We have Deschanel's 'Physics,' edited, or rather rewritten, by Prof. Everett, a book remarkable alike for the clearness of its explanations and for the beauty of the engravings with which it is illustrated; and, passing to works intended for students somewhat further advanced, we have the treatises of Prof. Balfour Stewart on heat, of Prof. Clerk Maxwell on the theory of heat, of Prof. Fleeming Jenkin on electricity, and we expect a similar threatise on light from another of our most distinguished members. These works breathe the very spirit of the method which should guide both research and education in physics. They express the most profound and far-reaching generalizations of science in the simplest language, and yet with the utmost precision. With the most sparing use of mathematical technicalities, they are a perfect storehouse of mathematical ideas and mathematical reasonings. An old French geometer used to say that a mathematical theory was never to be considered complete till you had made it so clear that you could explain it to the first man you met in the street. This is of course a brilliant exaggeration; but it is no exaggeration to say that the eminent writers to whom I have referred have given something

of this clearness and completeness to such abstract mathematical theories as those of the electrical potential, the action of capillary forces, and the definition of absolute temperature. A great object will have been attained when an education in physical science on the basis laid down in these treatises has become generally accepted in our schools.

I do not wish to close this Address without adverting, though only for one moment, to a question which occupies the minds of many of the friends of science at the present time—the question, What should be the functions of the State in supporting or organizing scientific inquiry? I do not mean to touch on any of the difficulties which attend this question, or to express any opinion as to the controversies to which it has given rise. But I do not think it can be out of place for the President of this Section to call your attention to the inequality with which, as between different branches of science, the aid of Government is afforded. National observations for astronomical purposes are maintained by this as by every civilized country. Large sums of money are yearly expended, and most rightly expended, by the Government for the maintenance of museums and collections of mineralogy, botany, and zoology. At a very recent period an extensive chemical laboratory, with abundant appliances for research as well as for instruction, has been opened at South Kensington. But for the physical sciences—such sciences as those of heat, light, and electricity—nothing has been done; and I confess I do not think that any new principle would be introduced, or any great burden incurred, capable of causing alarm to the most sensitive Chancellor of the Exchequer, if it should be determined to establish, at the national cost, institutions for the prosecution of these branches of knowledge, so vitally important to the progress of science as a whole. Perhaps, also, upon this general ground of fairness, even the pure mathematicians might prefer a modest claim to be assisted in the calculation and printing of a certain number of Tables, of which even the physical applications of their science are beginning to feel the pressing need.

One word further on this subject of State assistance to science, and I have done. It is no doubt true that for a great, perhaps an increasing, number of purposes science requires the assistance of the State; but is it not nearer to the truth to say that the State acquires the assistance of science? It is my conviction that if the true relations between science and the State are not recognized, it is the State, rather than science, that will be the great loser. Without science the State may build a ship that cannot swim, and may waste a million or two on experiments, the futile result of which science could have foreseen. But without the State science has done very well in the past, and may do very well in time to come. I am not sure that we should know more of pure mathematics, or of heat, of light, or electricity than we do at this moment if we had had the best help of the State all the time. There are, however, certain things which the State might do, and ought to do, for science. It, or corporations created by it, ought to undertake the responsibility of carrying on those great systems of observations which, having a secular character, cannot be completed within the lifetime of a single generation, and therefore cannot be safely left to individual energy. One other thing the State ought to do for science. It ought to pay scientific men properly for the services which they render directly to the State, instead of relying, as at present, on their love for their work as a means of obtaining their services on lower terms. If any one doubts the justice of this remark, I would ask him to compare the salaries of the officers in the British Museum with those which are in other departments of the Civil Service.

But what the State cannot do for science is to create the scientific spirit or to control it. The spirit of scientific discovery is essentially voluntary; voluntary, and even mutinous, it will remain: it will refuse to be bound with red tape, or ridden by officials, whether well meaning or perverse. You cannot have an Established Church in science; and if you had, I am afraid there are many scientific men who would turn scientific nonconformists.

I venture upon these remarks because I cannot help feeling that the great desire which is now manifesting itself on the part of some scientific men to obtain for science the powerful aid of the State may perhaps lead some of us to forget that it is self-reliance and self-help which have made science what it is, and that these are the qualities the place of which no Government help can ever supply.

Mathematics.

On the Mercator's Projection of a Surface of Revolution. By Prof. Cayley, *F.R.S.*

The theory of Mercator's projection is obviously applicable to any surface of revolution; the meridians and parallels are represented by two systems of parallel lines at right angles to each other, in such wise that for the infinitesimal rectangles included between two consecutive arcs of meridian and arcs of parallel the rectangle in the projection is similar to that on the surface. Or, what is the same thing, drawing on the surface the meridians at equal infinitesimal intervals of angular distance, we may draw the parallels at such intervals as to divide the surface into infinitesimal squares; the meridians and parallels are then in the projection represented by two systems of equidistant parallel lines dividing the plane into squares. And if the angular distance between two consecutive meridians instead of being infinitesimal is taken moderately small (5° or even 10°), then it is easy on the surface or *in plano*, using only the curve which is the meridian of the surface, to lay down graphically the series of parallels which are in the projection represented by equidistant parallel lines. The method is, of course, an approximate one, by reason that the angular distance between the two consecutive meridians is finite instead of infinitesimal.

I have in this way constructed the projection of a skew hyperboloid of revolution: viz. in one figure I show the hyperbola, which is the meridian section, and by means of it (taking the interval of the meridians to be $=10°$) construct the positions of the successive parallels; I complete the figure by drawing the hyperbolas which are the orthographic projections of the meridians, and the right lines which are the orthographic projections of the parallels; the figure thus exhibits the orthographic projection (on the plane of a meridian) of the hyperboloid divided into squares as above. The other figure, which is the Mercator's projection, is simply two systems of equidistant parallel lines dividing the paper into squares. I remark that in the first figure the projections of the right lines on the surface are the tangents to the bounding hyperbola; in particular, the projection of one of these lines is an asymptote of the hyperbola. This I exhibit in the figure, and by means of it trace the Mercator's projection of the right line on the surface; viz. this is a serpentine curve included between the right lines which represent two opposite meridians and having these lines for asymptotes. It is sufficient to show one of these curves, since obviously for any other line of the surface belonging to the same system the Mercator's projection is at once obtained by merely displacing the curve parallel to itself, and for any line of the other system the projection is a like curve in a reversed position.

A Mercator's projection might be made of a skew hyperboloid not of revolution; viz. the curves of curvature might be drawn so as to divide the surface into squares, and the curves of curvature be then represented by equidistant parallel lines as above; and the construction would be only a little more difficult. The projection presented itself to me as a convenient one for the representation of the geodesic lines on the surface, and for exhibiting them in relation to the right lines of the surface; but I have not yet worked this out. In conclusion, it may be remarked that a surface in general cannot be divided into squares by its curves of curvature, but that it may be in an infinity of ways divided into squares by two systems of curves on the surface, and any such system of curves gives rise to a Mercator's projection of the surface.

On some Curves of the Fifth Class. By Professor W. K. Clifford.

On a Surface of Zero Curvature and Finite Extent. By Professor W. K. Clifford.

On certain Propositions in the Theory of Numbers deduced from Elliptic-transcendent Identities. By J. W. L. GLAISHER, *B.A.*

The paper consisted of a series of propositions in the theory of numbers deduced from identities either actually or implicitly given in Jacobi's 'Fundamenta Nova' (Regiomonti, 1829), and of which the author believed some might be new. In this abstract the demonstrations are omitted, and only the enunciations of the propositions, with one or two examples of each, are given.

(i) Construct the following scheme:—

1	2	3	4	5	6	7	8	9	10	11	12	13	14	..
−3	−6	−9	−12	−15	−18	−21	−24	−27	−30	−33	−36	−39	−42	..
5	10	15	20	25	30	35	40	45	50	55	60	65	70	..
−7	−14	−21	−28	−35	−42	−49	−56	−63	−70	−77	−84	−91	−98	..
9	18	27	36	45	54	63	72	81	90	99	108	117	126	..
−11	−22	−33	−44	−55	−66	−77	−88	−99	−110	−121	−132	−143	−154	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

the mode of formation of which is evident; then strike out all the numbers that cancel one another, and every number that remains is either a square or is expressible as the sum of two squares; the converse proposition, that every number that is a square or is expressible as the sum of two squares will remain, is also true. Thus, $1=1^2$, $2=1^2+1^2$, 3 is cancelled, $4=2^2$, $5=2^2+1^2$, 6 and 7 are cancelled, $8=2^2+2^2$, 9 is cancelled in the 3-line, but reappears in the 9-line, so that it remains as it ought to do, since it $=3^2$, $10=3^2+1^2$, 11 and 12 are cancelled, &c.

(ii) Every number which is a square or expressible as the sum of two squares is of the form $2^l(4m-1)^2n$, n being any odd number, all of whose factors are of the form $4a+1$, and l and m any positive numbers; and if $\psi(n)$ denote the numbers of factors of n (unity and n itself included), then the number of ways in which $2^l(4m-1)^2n$ can be expressed as the sum of two squares $=\frac{1}{2}\psi(n)$; but if the number be a square, or the double of a square, the number of ways

$$=\tfrac{1}{2}\{\psi(n)-1\} \text{ or } \tfrac{1}{2}\{\psi(n)+1\}$$

respectively (0^2 not being counted as a square). From this many well-known theorems follow at once.

(iii) The following is the "sieve" corresponding to that in (i) for numbers that are the sum of two *odd* squares.

2	6	10	14	18	22	26	30	34	38	42	..
−6	−18	−30	−42	−54	−66	−78	−90	−102	−114	−126	..
10	30	50	70	90	110	130	150	170	190	210	..
−14	−42	−70	−98	−126	−154	−182	−210	−238	−266	−294	..
..	..	..	..	..	..	..	..	..	..	..	..

Every number that remains after the cancelling is the sum of two odd squares; and, *vice versâ*, every such number remains.

(iv) Every number that is the sum of two odd squares is of the form $2(4m-1)^2n$; and every such number can be expressed as the sum of two odd squares in $\frac{1}{2}\psi(n)$ ways, unless it is the double of a square, when, if of the form $2(4m-1)^2$, it cannot

be expressed as the sum of two unequal odd squares, and, if of the form $2(4m-1)^2r^2$, it can be so expressed in $\frac{1}{2}\{\psi(r^2)-1\}$ ways—the letters meaning as in (ii).

(v) Consider any number N, and let a be the number of ways in which it can be expressed as the sum of four squares, all different $(a^2+b^2+c^2+d^2)$; a_2 the number of ways, two of the four squares being identical $(2a^2+b^2+c^2)$; a_{22}, when two pairs of squares are identical $(2a^2+2b^2)$; a_3, when three squares are identical $(3a^2+b^2)$; and a_4 when all four are identical $(4a^2)$. Let β_1, β_2, β_3 be similar quantities denoting respectively the number of ways in which N can be expressed as the sum of three squares, with none, two, or three identical,

$$(a^2+b^2+c^2,\ 2a^2+b^2,\ 3a^2).$$

Let γ, γ_2, and δ be similar quantities for two squares and one square,

$$(a^2+b^2,\ 2a^2,\ a^2)\ ;$$

then

$$48a+24a_2+12a_{22}+8a_3+2a_4+24\beta+12\beta_2+4\beta_3+6\gamma+3\gamma_2+\delta$$

$=$ the sum of the factors of N, if N be odd,

and

$= 3\times$ (the sum of the factors of n) if N is even, and $= 2^r n$, n being odd.

Generally, several of the quantities a, a_2, &c. will vanish; and some must always, for two of the three β_3, γ_2, δ must be zero; also a_4 and δ vanish unless N is a square; a_{22}, a_1, and γ_2 vanish if N is odd; and the letters a_4, β_3, γ_2, and δ can only have the values 0 or 1.

Examples.—Take $N=81$; the factors are 1, 3, 9, 27, 81, of which the sum $=121$. And

$$81=36+25+16+4=64+9+4+4=64+16+1=49+16+16=36+36+9.$$

Therefore

$$a=1,\ a_2=1,\ \beta=1,\ \beta_2=2,\ \delta=1,\ \text{and}\ 48+24+24+12\times2+1=121.$$

Take $N=68=2^2.17$; and the sum of the factors of $17=18$, which multiplied by $3=54$. And $68=49+9+9+1=25+25+9+9=36+16+16=64+4$.
Therefore

$$a_2=1,\ a_{22}=1,\ \beta_2=1,\ \gamma=1,\ \text{and}\ 24+12+12+6=54.$$

(vi) A considerable reduction takes place when N is of the form $8n+7$, in which case the formula merely becomes

$$48a+24a_2+8a_3 = \text{sum of the factors of N}.$$

Example.—Take $N=63$; sum of factors $=104$, and

$$63=49+9+4+1=36+25+1+1=25+25+9+4=36+9+9+9.$$

Therefore

$$a=1,\ a_2=2,\ a_3=1,\ \text{and}\ 48+48+8=104.$$

(vii) Let A denote the number of ways in which any number N of the form $8n+4$ can be expressed as the sum of four odd squares, all different; A_2 the number of ways when two are identical; A_{22} when two pairs are identical; A_3 and A_4 when three and four respectively are identical. Then

$$24A+12A_2+6A_{22}+4A_3+A_4 = \text{sum of factors of}\ \tfrac{1}{4}N.$$

Example.—Take $N=84$, sum of factors of $\frac{1}{4}N=32$. And

$$84=49+25+9+1=25+25+25+9=81+1+1+1.$$

Therefore

$$A=1,\ A_3=2,\ \text{and}\ 24+8=32.$$

(viii) Let $[1^8]$ denote the number of ways in which any number N, divisible by 8, can be expressed as the sum of eight odd squares, all different; $[1^6 2]$ the number of ways when a pair are identical &c., so that, *e. g.* $[1^3 2 3]$ denotes the number

of ways in which N can be expressed in the form $a^2+b^2+c^2+2d^2+3e^2$; $[2^24]$ in the form $2a^2+2b^2+4c^2$ &c. Then

$$\begin{aligned}&40320[1^8]+20160[1^62]+6720[1^53]+10080[1^42^2]\\ &+1680[1^44]+3360[1^323]+336[1^35]+5040[1^22^3]\\ &+840[1^224]+1120[1^23^2]+56[1^26]+1680[12^23]\\ &+168[125]+280[134]+8[17]+2520[2^4]\\ &+420[2^24]+560[23^2]+28[26]+56[35]\\ &+70[4^2]+[8]=\chi(\tfrac{1}{8}N),\end{aligned}$$

$\chi(n)$ being the sum of the cubes of all the factors of n $(=\frac{1}{8}N)$ which are such that when n is divided by any of them the quotient is odd, viz. $\chi(n)=\Sigma a^3$, a being any factor of n such that $\frac{n}{a}$ is odd.

Example.—Take N=96; therefore $\frac{1}{8}N=12=1.12=2.6=3.4$, so that the only factors that have odd cofactors are 12 and 4, whence $\chi(\frac{1}{8}N)=12^3+4^3=1792$. And

$$\begin{aligned}96&=49+25+9+9+1+1+1+1=81+9+1+1+1+1+1+1\\ &=49+9+9+9+9+9+1+1=25+25+9+9+9+9+9+1\\ &=25+25+25+9+9+1+1+1.\end{aligned}$$

Therefore

$$[1^224]=1,\ [1^26]=1,\ [125]=2,\ [23^2]=1,\quad\text{and } 840+56+336+560=1792.$$

(ix) Every number that is the sum of six odd squares is of the form $8n+6$; and if the half of such a number, being of the form $4n+3$, be resolved in any manner into two factors, one must be of the form $4n+1$ and the other of the form $4n+3$. Adopting a notation similar to that described in (viii), if $2s$ denotes any number of the form $8n+6$,

$$\begin{aligned}720[1^6]+360[1^42]+120[1^33]+180[1^22^2]+30[1^24]+60[123]+6[15]\\ +90[2^3]+15[24]+20[3^2]+[6]=\tfrac{1}{8}\xi(s),\end{aligned}$$

where $\xi(s)$ = sum of the squares of all the factors of s that are of the form $4n+3$, − sum of the squares of all those that are of the form $4n+1$.

Examples.—Take $2s=30$, then

$$s=1\,.\,15=3\,.\,5;\ \therefore\ \xi(s)=15^2+3^2-5^2-1^2=208,\quad\text{and } \tfrac{1}{8}(208)=26.$$

And $\quad 30=25+1+1+1+1+1=9+9+9+1+1+1.$

Therefore $[15]=1$, $[3^2]=1$, and $6+20=26$.

Take $2s=270$, then

$$s=135,\text{ and } \xi(s)=135^2+27^2+15^2+3^2-45^2-9^2-5^2-1=17056,$$

so that $\frac{1}{8}\xi(s)=2132$. And it will be found that the decomposition into squares gives

$$[1^42]=1,\ [1^33]=1,\ [1^22^2]=7,\ [1^24]=2,\ [123]=5,\ [15]=2,\ [3^2]=1,$$

and

$$360+120+1260+60+300+12+20=2132.$$

(*) The above are the principal theorems proved, which were illustrated by several other examples. The paper concluded with an algebraical proof of the identity

$$(1-2x+2x^4-2x^9+\ldots)^4+(2x^{\frac{1}{4}}+2x^{\frac{9}{4}}+2x^{\frac{25}{4}}+\ldots)^4=(1+2x+2x^4+2x^9+\ldots)^4,$$

which resulted from the development of a process indicated by Gauss in his memoir "Zur Theorie der neuen Transscendenten," Werke, t. iii. p. 447.

[Since the paper, of which the above is an abstract, was read, Prof. H. J. S. Smith, who kindly looked through it at the author's request, has pointed out to him that most of the theorems contained in it had been previously published by Jacobi, Eisenstein, and himself, though expressed in a somewhat different form. For references see Prof. Smith's Report on the Theory of Numbers, Part VI. art. 127 (British Association Report, 1865, pp. 335–338).]

On the Negative Minima of the Gamma function.
By J. W. L. GLAISHER, *B.A.*

The definition of the gamma function usually adopted is in effect, that between the values 0 and 1 of x it is defined by the equation $\Gamma(x+1)=\int_0^\infty v^x e^{-v} dv$, and for all other values of x by the equation $\Gamma(x+1)=x\Gamma(x)$.

The curve $y=\Gamma(x)$ has a minimum corresponding to $x=1{\cdot}4616321\ldots$, as is well known; but as $\Gamma(x)$ is infinite whenever x is a negative integer, there are minima values of $\Gamma(x)$ between $x=-1$ and -2, -2 and -3, &c. The author had determined the positions of the first ten of these minima (or, algebraically considered, minima and maxima alternately) to four places of decimals, and also their values, the chief object being to obtain data to form a moderately accurate drawing of the curve. The abscissæ of the minima were found by the aid of the table of $\Psi(x)$ in Gauss's Göttingen memoir of 1812 and Oakes's Table of Reciprocals, as follows. Writing, with Gauss, $\Pi(x)$ for $\Gamma(x+1)$ and logf x (Gauss's $\Psi(x)$) for $\Pi'(x)\div\Pi(x)$, the first minimum corresponds to the abscissa $-1+$the root of

$$\operatorname{logf} x=\frac{1}{x}+\frac{1}{x-1};$$

the second to the abscissa, $-2+$ the root of

$$\operatorname{logf} x=\frac{1}{x}+\frac{1}{x-1}+\frac{1}{x-2};$$

the third to $-3+$ the root of

$$\operatorname{logf} x=\frac{1}{x}+\frac{1}{x-1}+\frac{1}{x-2}+\frac{1}{x-3}\ \ \&\text{c.}$$

On the Introduction of the Decimal Point into Arithmetic.
By J. W. L. GLAISHER, *B.A.*

The following is an extract from Peacock's excellent history of Arithmetic in the 'Encyclopædia Metropolitana,' which forms the standard (not to say the only) work on the subject. Speaking of Stevinus's 'Arithmétique,' Peacock writes:—"We find no traces, however, of decimal arithmetic in this work; and the first notice of *decimal*, properly so called, is to be found in a short tract which is put at the end of his 'Arithmétique' in the collection of his works by Albert Girard, entitled 'La Disme.' It was first published in Flemish, about the year 1590, and afterwards translated into barbarous French by Simon of Bruges.... Whatever advantages, however, this admirable invention, combined as it still was with the addition of the exponents, possessed above the ordinary methods of calculation in the case of abstract or concrete fractions, it does not appear that they were readily perceived or adopted by his contemporaries.... The last and final improvement in this *decimal Arithmetic*, of assimilating the notation of integers and *decimal* fractions, by placing a *point* or *comma* between them, and omitting the exponents altogether, is unquestionably due to the illustrious Napier, and is not one of the least of the many precious benefits which he conferred upon the science of calculation. No notice whatever is taken of them in the 'Mirifici Logarithmorum Canonis Descriptio,' nor in its accompanying tables, which was published in 1614. In a short abstract, however, of the theory of these logarithms, with a short table of the logarithms of natural numbers, which was published by Wright, 1616, we find a few examples of decimals expressed with reference to the decimal point; but they are first distinctly noticed in the 'Rabdologia,' which was published in 1617. In an 'Admonitio pro decimali Arithmetica' he mentions in terms of the highest praise the invention of Stevinus, and explains his notation; and, without noticing his own simplification of it, he exhibits it in the following example, in which it is required to divide 861094 by 432.... The quotient is 1993,273 or 1993,2′7″3‴, the form under which he afterwards writes it, in partial

conformity with the practice of Stevinus. The same form is adopted in an example of abbreviated multiplication which subsequently occurs.... The preceding statement will sufficiently explain the reason why no notice is taken of *decimals* in the elaborate explanations which are given by Napier, Briggs, and Kepler, of the theory and construction of logarithms; and indeed we find no mention of them in any English author between 1619 and 1631. In that year the 'Logarithmicall Arithmetike' was published by Gellibrand and other friends of Briggs (who died the year before), with a much more detailed and popular explanation of the doctrine of logarithms than was to be found in the 'Arithmetica Logarithmica.'....From this period we may consider the decimal Arithmetic as fully established, inasmuch as the explanation of it began to form an essential part of all books of practical arithmetic. The simple method of marking the separation of the decimals and integers by a comma, of which Napier has given a solitary example, was not, however, generally adopted."

De Morgan ('Arithmetical Books,' 1847, p. xxiii) writes:—"Dr. Peacock mentions Napier as being the person to whom the introduction [of the decimal point] is unquestionably due, a position which I must dispute upon additional evidence. The inventor of the single decimal distinction, be it point or line, as in 123·456 or 123|456, is the person who first made this distinction a permanent language, not using it *merely as a rest in a process*, to be useful in pointing out afterwards how another process is to come on or language is to be applied, but making it his final and permanent indication as well of the way of pointing out where the integers end and the fractions begin, as of the manner in which that distinction modifies operations. Now, first, I must submit that Napier did not do this; secondly, that if he did do it, Richard Witt did it before him."

De Morgan then states that he has not seen Wright's translation of 1616; but he proceeds to examine Napier's claim as resting on the two examples in the 'Rabdologia,' in the first of which a comma is used, but only in one place. After this examination he proceeds:—"I cannot trace the decimal point in this; but if required to do so, I can see it more distinctly in Witt, who published four years before Napier. But I can hardly admit him to have arrived at the notation of the decimal point...." *

I agree with De Morgan in all that he has stated in the above extracts, and do not think that the single instance of the comma used in the course of work, and replaced immediately afterwards by exponential marks, is a sufficient ground for assigning to Napier the invention of the decimal point, or even affords a presumption that he made use of it at all in the expression of results.

Still one of the objects of this paper is to claim (provisionally, of course, till evidence of any earlier use is produced, if such there be) the invention of the decimal point for Napier, but not on account of any thing contained in the 'Rabdologia.' The mathematical works published by Napier in his lifetime (he died in 1617) were his 'Mirifici Logarithmorum Canonis Descriptio,' 1614, containing the first announcement of the invention of logarithms, and the 'Rabdologia,' 1617, giving an account of his almost equally remarkable (as it was thought at the time) invention of numbering rods or "bones." In 1619, two years after his death, the 'Mirifici Logarithmorum Canonis Constructio,' containing the method of construction of the canon of logarithms, was published, edited by his son; and in this work the decimal point is systematically used in a manner identical with that in which we employ it at the present day. I can find no traces of the decimal point in Wright's translation of the 'Descriptio,' 1616; and, as De Morgan says, the use of the decimal separator is not apparent in Witt. The earliest work, therefore, in which a decimal separator was employed seems to be Napier's posthumous work the 'Constructio' (1619), where the following definition of the point occurs on p. 6:—"In numeris periodo sic in se distinctis, quicquid post periodum notatur fractio est, cujus denominator est unitas cum tot cyphris post se,

* In an essay "On some points in the history of Arithmetic" (Companion to the Almanac for 1851), De Morgan has further discussed the invention of the decimal point, but in the same spirit as regards Napier. He seems never to have seen Napier's 'Constructio' of 1619; and the work is very rare. The only copy I have been able to see is that in the Cambridge University Library.

quot sunt figuræ post periodum. Ut 10000000·04 valet idem, quod $10000000\frac{4}{100}$. Item 25·803, idem quod $25\frac{803}{1000}$. Item 9999998·0005021, idem valet quod $9999998\frac{5021}{10000000}$, & sic de cæteris." On p. 8 we have 10·502 multiplied by 3·216, and the result found to be 33·774432; and on pp. 23 and 24 occur decimals not attached to integers, viz. ·4999712 and ·0004950. These show that Napier was in possession of all the conventions and attributes that enable the decimal point to complete so symmetrically our system of notation, viz. (1) he saw that a point or separatrix was quite enough to separate integers from decimals, and that no signs to indicate primes, seconds, &c. were required; (2) he used ciphers after the decimal point and preceding the first significant figure; and (3) he had no objection to a decimal standing by itself without any integer. Napier thus had complete command over decimal fractions, and understood perfectly the nature of the decimal point; and I believe (except, perhaps, Briggs) he is the first person of whom this can be said. When I first read the 'Constructio' I felt some doubt as to whether Napier really appreciated the value of the decimal point in all its bearings, as he seemed to have regarded it to some extent as a mark to separate figures that were to be rejected from those that were to be retained; but a careful examination has led me to believe that his views on the subject were pretty nearly identical with those of a modern arithmetician. There are perhaps 200 decimal points in the book, affording abundant evidence on the subject.

The claim of Napier to the invention of the decimal point is not here noticed for the first time, as both Delambre ('Hist. de l'Astron. mod.,' t. i. p. 497) and Hutton allude to the decimal fractions in the 'Constructio' (though the latter claims priority for Pitiscus), and Mr. Mark Napier ('Memoirs of John Napier,' p. 454) devotes a good deal of space to it.

Briggs also used decimals, but in a form not quite so convenient as Napier. Thus he writes 63·0957379 as $63\underline{0957379}$, viz. he prints a bar under the decimals: this notation first appears, without any explanation, in his 'Lucubrationes,' appended to the 'Constructio'"*. Briggs used this notation all his life (he died in 1631), and he explains it in the 'Arithmetica Logarithmica' of 1624. Oughtred's symbol, first used (as far as I know) in his 'Arithmeticæ in numeris . . . Clavis,' 1631, differed only from Briggs's in the insertion of a vertical bar to separate the decimals from the integers more completely—thus, $63\lfloor\underline{0957379}$. Oughtred's and Briggs's notations are essentially the same, the improvement of the former being no doubt due to the uncertainty that sometimes might be felt as to which was the first figure above Briggs's line. From an inspection of MSS. of Briggs and Oughtred (the Birch MSS. contain a letter of Briggs to Pell; and the Royal Society has a Peter Ramus, with many of his MS. notes, while the Cambridge University copy of the 'Constructio' is annotated in MS. by Oughtred) it is apparent that, in writing, Briggs and Oughtred both made the separating rectangle in exactly the same way; viz. they wrote it $63\lfloor\overline{0957379}$, the upright mark usually being just high enough to fix distinctly what two figures it was intended to separate, and they rarely took the trouble to continue the horizontal line to the end of the decimals if there were many. Thus Oughtred was a follower of Briggs, and only made an improvement in the *printed* notation. It is clear that, in writing, Briggs's rectangle was pretty nearly as convenient as Napier's point; and there is every probability that Briggs appreciated all the properties of the "separatrix" as clearly as Napier; but in his 8 pp. of 'Lucubrationes' he has left much less to judge by than has Napier. In 1624, as we can see from his 'Arithmetica Logarithmica,' he had full command over decimal arithmetic in its present form (except that he used the rectangular "separatrix" instead of the point. Gunter was a follower of Napier, and employed the point (but see De Morgan). In his 'Description and use of the Sector' (1623) he uses the point throughout pretty much as we do at present (*e.g.* p. 40 of the 'First Booke of the Crosse-Staffe,' "As 4·50 unto 1·00: so 1·000 unto 0·222"), except that he called the decimals *parts* in the text. In Roe's

* A curious blunder is made in Bartholomew Vincent's reprint of the 'Constructio,' Lyons, 1620 (of which there is a copy in the Royal Society's Library). The printer, unaware that the position of Briggs's subscript rules had any meaning, has disposed them symmetrically under all the figures.

'Tabulæ Logarithmicæ, or Two Tables of Logarithmes' (1633), the explanatory portion of which was written by Wingate, decimal points are used everywhere; thus we have (p. 29) "As 1 is to ·079578 : so is the square of the circumference to the superficiall Content;" and he takes the case of circumference 88·75, and obtains by multiplication (performed by logarithms) 626·8 for the result. Wingate refers for explanation on the decimal point to his 'Arithmetic;' but I have not seen any edition of this work that was published previously to Roe's tables (Watt gives one 1630). In his 'Construction and Use of the Line of Proportion,' 1628, Wingate also uses decimals and decimal points.

On the whole, therefore, it appears that both Napier and Briggs saw that a mere separator to distinguish integers from decimals was quite sufficient without any exponential marks being attached to the latter—but that Napier used a simple point for the purpose, while Briggs employed a bent or curved line, for which in print he substituted merely a horizontal bar subscript to the decimals—that Gunter and Wingate followed Napier, while Oughtred adopted Briggs's method and made an improvement in the mode of *printing* it. Napier has left so many instances of the decimal point as to render it pretty certain that he thoroughly appreciated its use; and there is every reason to believe that Briggs had (in 1619) an equal command over his separator, although there are not enough printed instances of that date to prove it so conclusively as in Napier's case (there is no instance in the 'Lucubrationes' in which a quantity begins with a decimal point; and there could not well be one). Napier did not use the decimal point in the 'Descriptio' (1614), nor in his book of arithmetic, first printed under the editorship of Mr. Mark Napier in 1839; and there is only the single doubtful case in the 'Rabdologia,' 1617; so that there is reason to believe that he did not regard it as generally applicable in ordinary arithmetic. The only previous publication of Briggs's that I have seen is his 'Chilias,' 1617, which contains no letterpress at all. The fact that Napier and Briggs use different separating notations is an argument against either having been indebted to the other, as whoever adopted the other's views would probably have accepted his separator too. It is doubtful whether, if Napier had written an ordinary arithmetic at the close of his life, he would have used his decimal point. Wingate employed the point with much more boldness, and regarded it much more in the light of a permanent symbol of arithmetic than did (or could) Napier. The Napierian point and the Briggian separator differ but little in writing; and as far as MS. work is concerned it is quite easy to see why many should have considered the latter preferable; for it was clear, and interfered with no existing mark. A point is the simplest separator possible; but it had already another use in language. In all the editions of Oughtred's 'Clavis' (which work held its ground till the beginning of the last century) the rectangular separator was used; and it is not unlikely that it was ultimately given up, for the same reason as that which I believe will lead to the abandonment of the similar sign now used in certain English books to denote factorials, viz. because it was troublesome to *print*. But be this as it may, it is not a little remarkable that the first separator used (or, more strictly, one of the first two) should have been that which was finally adopted after a long period of disuse. All through the seventeenth century exponential marks seem to have been common, on which see the accounts in Sir Jonas Moore's 'Moor's Arithmetick,' London, 1660, p. 10, and Samuel Jeake's 'Compleat Body of Arithmetick,' London, 1701 (written in 1674), p. 208, which are unfortunately too long to quote in this abstract.

In his account Peacock is inaccurate in saying that the 'Logarithmicall Arithmetike' was published by Gellibrand and others, the mistake having arisen no doubt from a confusion with the 'Trigonometria Britannica,' 1633; and in any case the reference is not a good one, as the 'Arithmetike' of 1631 shows (for reasons which must be passed over here) a less knowledge of decimal arithmetic than do any of the chief logarithmic works of this period. Also Briggs died in 1631, not 1630.

There is no doubt whatever that decimal fractions were first introduced by Stevinus in his tract 'La Disme.' De Morgan ('Arithmetical Books,' p. 27) is quite right in his inference that it appeared in French in 1585 attached to the 'Pratique d'Arithmétique.' A copy of this work (1585) with 'La Disme' appended is now

in the British Museum. On the titlepage of the 'Disme' are the words "Premierement descripte en Flameng, & maintenant conuertie en Francois, par Simon Stevin de Bruges." These words, appearing also in Albert Girard's collected edition of Stevinus's works (1634), no doubt gave rise to De Morgan's inference that "the method of decimal fractions was announced before 1585 in Dutch." The Cambridge University Library possesses a 1585 copy entitled "De Thiende . . . Beschreven door Simon Stevin van Brugghe . . . . . Tot Leyden, By Christoffel Plantijn, M.D.LXXXV" (privilege dated December 20, 1584); and there seems every reason to believe, in the absence of any evidence to the contrary, that this was the first edition of this celebrated tract. Peacock's statement that "it was first published in Flemish about the year 1590, and afterwards translated into barbarous French by Simon of Bruges," is also, I suspect, founded on no other evidence than the sentence on the titlepage of the 'Disme,' which appears also in Girard. De Morgan rightly remarks that Simon of Bruges is Stevinus himself, but he cannot tell whence Peacock derived the date 1590. It is probable that it was merely a rough estimate obtained by considering the dates of the other works of Stevinus.

Stevinus's method involved the use of his cumbrous exponents: thus he wrote 27·847 as 27 ⓪ 8 ① 4 ② 7 ③, and read it 27 commencements, 8 primes, 4 seconds, 7 thirds; and the question chiefly noticed in this abstract is the consideration of who first saw that, by a simple notation, the exponents might be omitted, and introduced this abbreviation into arithmetic.

Napier's 'Rabdologia' was translated into several languages soon after its appearance; and I have taken some pains to examine the different ways in which the translators treated the example which Peacock regarded as the first use of the decimal point, as we can thereby infer something with regard to the state of decimal arithmetic in the different countries. Napier (1617) wrote 1993,273 in the work and 1993,2′7″3‴ in the text. In Locatello's translation (Verona, 1623) this is just reversed, viz. there is 1993.2′7″3‴ in the work and 1993,273 in the text. The Lyons edition (1626) has 1993,273 in the work and 1993,2 ① 7 ② 3 ③ in the text, while De Decker's edition (Gouda, 1626) has 1993,273 in the work, and in the text 1993 ⓪ 2 ① 7 ② 3 ③, the last being exactly as Stevinus would have written it. Ursinus's 'Rhabdologia Neperiana,' Berlin, 1623, is not an exact translation; and the example in question does not occur there.

Some Suggestions towards the Formation of an extended Table of Logarithms.
By G. O. Hanlon.

On the Theory of Differential Resolvents.
By the Rev. Robert Harley, *F.R.S.*

In the earlier development of the theory of differential resolvents attention was confined almost exclusively to certain trinomial forms of algebraic equations, and the resolvents were calculated for these forms. A connexion not before noticed was found to exist between algebraic and differential equations; and results remarkable for their simplicity and elegance were obtained. Some of these results have been laid before the Section at former Meetings (see Reports of the Association, 'Transactions of Sections,' 1862, pp. 4, 5; 1865, p. 6; 1866, pp. 2, 3).

Every differential resolvent may be regarded under two distinct aspects: it may be considered either (first) as giving in its complete integration the solution of the algebraic equation from which it has been derived, or (secondly) as itself solvable by means of that equation. The two equations, the algebraic and the differential, are in fact *coresolvents*. The subject was first considered in the former aspect by Sir James Cockle, the originator of the theory, and by Mr. Harley; and their researches will be found embodied in various papers published in the 'Phi-

losophical Magazine,' the 'Quarterly Journal of Mathematics,' the 'Manchester Memoirs,' and the 'Proceedings of the London Mathematical Society.' It has been shown that every differential resolvent is satisfied, not only by each of the roots, but also by each of the constituents of the roots of the algebraic equation to which it belongs, and that these constituents are in fact the particular integrals of the resolvent equation. In the latter aspect every differential resolvent of the form

$$u+\phi(\mathrm{D})e^{n\theta}u=0=\mathrm{U},\ \left[\mathrm{D}=\frac{d}{d\theta}\right],$$

in which θ is a variable parameter, and u considered as a function of θ is a root of a certain algebraic equation of the $(n+1)$th degree, gives, when U is of an order higher than the second, a new primary form—that is to say, a form not recognized as primary in the late Professor Boole's theory. And in certain cases in which the dexter of the defining equation does not vanish, a comparatively easy transformation will rid the equation of the dexter term; and the resulting differential equation will be of a new primary form. The same transformation which deprives the algebraic equation of its second term will deprive the differential equation of its dexter term.

Boole, in his last paper before the Royal Society, entitled "On the Differential Equations which determine the form of the Roots of Algebraic Equations," remarks:—"While the subject seems to be more important with relation to differential than with reference to algebraic equations, the connexion into which the two subjects are brought must itself be considered as a very interesting fact. As respects the former of these subjects, it may be observed that it is a matter of quite fundamental importance to ascertain for what forms of the function $\phi(\mathrm{D})$, equations of the type

$$u+\phi(\mathrm{D})e^{n\theta}u=0$$

admit of finite solution. We possess theorems which enable us to deduce from each known integrable form an infinite number of others. Yet there is every reason to think that the number of really primary forms (of forms the knowledge of which, in combination with such known theorems, would enable us to solve all equations of the above type that are finitely solvable) is extremely small. It will indeed be a most remarkable conclusion, should it ultimately prove that the forms in question stand in absolute and exclusive connexion with the class of algebraic equations here considered." (Phil. Trans. for 1864, p. 733 *et seq.*)

In his later researches the author of this paper has sought to determine the form of the differential resolvents of algebraic equations whose terms are complete, and whose coefficients are unmodified. Mr. Spottiswoode has also considered the question in this its most general aspect; and in a short paper on "Differential Resolvents," printed in the second volume of the third series of the 'Manchester Memoirs,' pp. 227–232, he has exemplified a method of finding the resolvents in the cases of quadratics and cubics, which is directly applicable to all degrees. This method, considered as a *working* process, possesses some advantages over that employed by Sir James Cockle and Mr. Harley in dealing with trinomial forms. Its chief peculiarity consists in effecting all necessary eliminations by means of determinants.

Beginning with the quadratic

$$(a,\ b,\ c)\ (x,\ 1)^2=0,$$

which gives

$$2(a,\ b)\ (x,\ 1)\ x'+(a',\ b',\ c')\ (x,\ 1)^2=0,$$

where differentiation with respect to the parameter is indicated by accents, Mr. Spottiswoode forms a system of equations from which by the elimination of all powers of x higher than the first, he deduces

$$\begin{vmatrix} -2x' & a' & 2b' & c' \\ . & a & 2b & c \\ 1 & . & a & b \\ x & a & b & . \end{vmatrix}=0,$$

the differential resolvent required. The developed form is

$$2a(ac-b^2)x'-\{a'(2b^2-ac)-2b'ab+c'a^2\}x-a'bc+2b'ca-c'ab=0,$$

a result which had been otherwise obtained previously by both Sir James Cockle and Mr. Harley.

Proceeding to the cubic

$$(a,\ b,\ c,\ d)\ (x,1)^3=0,$$

Mr. Spottiswoode, with some assistance in the reductions from the author, finds that the resolvent may be concisely written in the form

$$\mathrm{AE}x''+\left\{\begin{vmatrix}\mathrm{A}' & \mathrm{A}\\ \mathrm{E}' & \mathrm{E}\end{vmatrix}+\frac{3\mathrm{E}}{a}(2b\,\mathrm{E}-a\mathrm{F})\right\}x'$$

$$+\begin{vmatrix}\cdot & \mathrm{E}' & \mathrm{E}\\ 1 & \mathrm{F}' & \mathrm{F}\\ x & \mathrm{G}' & \mathrm{G}\end{vmatrix}-2\mathrm{E}\begin{vmatrix}\cdot & \cdot & a' & 3b' & 3c' & d'\\ \cdot & a' & 3b' & 3c & d' & \cdot\\ \cdot & \cdot & a & 3b & 3c & d\\ \cdot & a & 3b & 3c & d & \cdot\\ 1 & \cdot & \cdot & a & 2b & c\\ x & \cdot & a & 2b & c & \cdot\end{vmatrix}=0,$$

in which the values of A, E, F, G are as follow :—

$$\frac{\mathrm{A}}{a}=\begin{vmatrix}a & 2b & c & \cdot\\ b & 2c & d & \cdot\\ \cdot & b & 2c & d\\ \cdot & a & 2b & c\end{vmatrix}=a^2d^2-6abcd+4ac^3+4b^3d-3b^2c^2,$$

the discriminant of the cubic.

$$\frac{3\mathrm{E}}{a}=\begin{vmatrix}a' & 3b' & 3c' & d'\\ a & 3b & 3c & d\\ a & 2b & c & \cdot\\ \cdot & a & 2b & c\end{vmatrix}=\begin{array}{l}a'\ (-acd+4b^2d-3bc)\\ -6b'a(bd-c^2)\\ +3c'a(ad-bc)\\ -2d'a(ac-b^2).\end{array}$$

$$\frac{3\mathrm{F}}{a}=\begin{vmatrix}a' & 3b' & 3c' & d'\\ a & 3b & 3c & d\\ b & 2c & d & \cdot\\ \cdot & a & 2b & c\end{vmatrix}=\begin{array}{l}a'(-ad^2+7bcd-6c^3)\\ -3b'(acd+2b^2d-3bc^2)\\ +3c'(abd+2ac^2-3b^2c)\\ +\ d'(a^2d-7abc+6b^3).\end{array}$$

$$\frac{3\mathrm{G}}{a}=\begin{vmatrix}a' & 3b' & 3c' & d'\\ a & 3b & 3c & d\\ a & 2b & c & \cdot\\ b & 2c & d & \cdot\end{vmatrix}=\begin{array}{l}2a'd\,(bd-c^2)\\ -3b'd\,(ad-bc)\\ +6c'd\,(ac-b^2)\\ +\ d'\ (abd-4ac^2+3b^2c).\end{array}$$

Attempts have been made to exhibit the cubic resolvent as a single determinant, but hitherto without success, the only result obtained (a determinant of the 16th degree) having proved illusory. The author has developed the resolvent in the case of $a=1$, and he finds that it contains 203 terms. He has also nearly completed the calculation of the cubic resolvent when the coefficients are all unmodified. He hopes shortly to publish these results.

Eight years ago, at the Meeting in Birmingham, Mr. Spottiswoode communicated to the author a method of solving algebraic equations by integration which may be conveniently noticed here.

Let the general equation of the nth degree be represented by

$$(a,\ b,\ldots)\ (x,1)^n=0;\qquad\qquad (1)$$

then, differentiating on the supposition that the coefficients are all functions of a single variable, we have

$$n(a,\ b,\ldots)\ (x,1)^{n-1}\partial x+(\partial a,\ \partial b,\ldots)\ (x,1)^n=0.\qquad\qquad (2)$$

Now the coefficient of any term x^{n-i} in the first part of the above equation

$$=n\frac{(n-1)(n-2)..(n-i+1)}{1.2..(i-1)}=in\frac{(n-1)..(n-i+1)}{1.2..i}=i[n,1], \text{ say.}$$

Hence (2) may be written thus,

$$(\partial a, a\partial x+\partial b, 2b\partial x+\partial c, ..)(x,1)^n=0; \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

or putting $\frac{\partial a}{dx}=a'$, $\frac{\partial b}{dx}=b'$, .., (3) becomes

$$(a', a+b', 2b+c', ..)(x,1)^n=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Now the resultant of (1) and (4) with respect to x is

$$\begin{vmatrix} a & [n,1]\,b & [n,2]\,c & . & . \\ . & a & [n,1]\,b & . & . \\ . & . & a & . & . \\ \vdots & \vdots & \vdots & & \\ a' & [n,1](b'+a) & [n,2](c'+2b) & . & . \\ . & a' & [n,1](b'+a) & . & . \\ . & . & a' & & \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{vmatrix}=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

And if any one of the minors formed from the n upper lines of (5) be represented by F $(a, b, ..)$, and the complementary one formed from the n lower ones by F_1 $(a', b'+a, ..)$, and if further we write F, F_1 for F $(a, b, ..)$, F_1 $(a', b', ..)$ respectively, then (5) may be written thus:—

$$0=\Sigma\,\text{F}\,(a,b,..)\text{F}_1\,(a', b'+a, ..)=\Sigma\text{FF}_1+\Sigma\nabla\text{FF}_1+\Sigma\frac{\nabla^2}{1.2}\text{FF}_1+.., \quad . \quad (6)$$

where

$$\nabla=a\frac{\partial}{db}+2b\frac{\partial}{dc}+3c\frac{\partial}{dd}+.. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The last two terms of (6) offer some peculiarity. In fact it is not difficult to see, by reference to (5) and (7), that the last term, viz. $\Sigma\frac{1}{1.2..n}\nabla^n\text{FF}_1$ is $=a^2\square$, where $\square$ is the discriminant of (1). Also if we multiply (6) throughout by ∂x^n, the last term but one divided by the last will be the coefficient of ∂x^{n-1} in an equation for determining dx; in other words, it will be $=-\Sigma dx=n\,\partial\left(\frac{b}{a}\right)=\frac{n}{a^2}(a\,\partial b-b\,\partial a)$.

So that
$$\frac{1}{1.2..(n-1)}\Sigma\,\nabla^{n-1}\text{F}\,\text{F}_1=n(a\,\partial\,b-b\,\partial\,a)\square;$$

and the last two terms of (6) are consequently

$$=a^2\square\partial(n\frac{b}{a}+x). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Consider the cases of $n=2$, and $n=3$. For the quadratic $(a, b, c)(x, 1)^2=0$ (6) takes the form

$$4a^2(ac-b^2)+8(ac-b^2)(ab'-a'b)-4(bc'-b'c)(ab'-a'b)+(ac'-a'c)=0;$$

and if we subject the variability of the coefficients to the single condition $ab'-a'b=0$, the resultant reduces to

$$\frac{ac'-a\,c}{a}=a\frac{\partial}{dx}\frac{c}{a}=\pm 2\sqrt{(b^2-ac)},$$

whence
$$\partial x=\pm\frac{a}{2\sqrt{(b^2-ac)}}\partial\frac{c}{a};$$

or integrating and determining the constant by the condition that, when $c=0$, $x=0$, we finally obtain the usual solution,

$$x=-\frac{b}{a}\pm\frac{1}{a}\sqrt{(b^2-ac)}.$$

Next, for the cubic $(a, b, c, d)(x, 1)^3=0$, ΣFF_1 becomes

$$\begin{vmatrix} a & 3b & 3c & d & . & . \\ a' & 3b' & 3c' & d & . & . \\ . & a & 3b & 3c & d & . \\ . & a' & 3b' & 3c' & d' & . \\ . & . & a & 3b & 3c & d \\ . & . & a' & 3b' & 3c' & d' \end{vmatrix}=0;$$

and when written under this form it is seen that it is a cubic function of the determinants

$$\left\|\begin{matrix} a & b & c & d \\ a' & b' & c' & d' \end{matrix}\right\|;$$

or writing $ab'-a'b=(ab)$, &c., ΣFF_1 becomes

$$81(ab)(bc)(cd)+18(ab)(ad)(cd)-27(ab)(bd)^2$$
$$+9(ac)(ad)(bd)-27(cd)(ac)^2-(ad)^3=0.$$

Also $\quad \nabla(ab)=a^2, \quad \nabla(ac)=2ab, \quad \nabla(ad)=3ac,$

$$\nabla(bc)=2b^2-ac,\ \nabla(bd)=3bc-ad,\ \nabla(cd)=3c^2-2bd.$$

By means of these formulæ ∇FF_1 may be easily calculated; and thence, with the help of (8), the entire value of the resultant for the cubic will be found. If, however, as in the case of the quadratic, we make $(ab)=0$, and then reduce by means of the identical equation

$$b(cd)+c(db)+d(bc)=0,$$

we find that

$$\Sigma FF_1=\frac{a^2}{b^2}\{-a(bd)^3+9b(bd)^2(bc)-27(bd)(bc)^2+27(bc)^3\}$$

and

$$\nabla\Sigma FF_1=9\frac{a^2}{b^2}\{(ac-b^2)(bd)^2-3(ad-bc)(bd)(bc)+9(bd-c)^2(bc)^2\},$$

so that $\nabla\Sigma FF_1$ is *à une facteur près*, the Hessian of ΣFF_1. In fact the whole equation (5) takes the form

$$V-\tfrac{3}{2}bH(V)b^3+\square(V)=0,$$

in which

$$V=a(bd)^3-9b(bd)^2(bc)+27(bd)(bc)^2+27(bc)^3.$$

If, further, we make $a'=0$ and $b'=0$, the above expression retains the same form, only in it d' takes the place of (bd), and c' of (bc). Finally, if we also make $c'=0$, we have

$$\left[3(b^2-ac)+\frac{ad'}{3}\right]\frac{d'^2}{9}+\square=0;$$

whence, substituting $-d'=3(ax^2+2bx+c)$,

$$\frac{\partial d}{\sqrt{-\square}}=\frac{3dx}{\sqrt{\{4(b^2-ac)-(ax+b)^2\}}},$$

$\square$ being now regarded as a function of d, the only remaining variable; so that x may be determined by integration, as in the case of the quadratic.

Those who are interested in this subject may compare the foregoing method with that exemplified by the author in his paper entitled "On the Theory of the Transcendental Solution of Algebraic Equations," Quarterly Journal of Mathematics, vol. v. pp. 337–360.

Remarks on Professor Evans's *Method of solving Cubic and other Trinomial Equations. By the* Rev. ROBERT HARLEY, *F.R.S.*

Sur l'Irrationalité de la Base des Logarithmes Hyperboliques. Par CH. HERMITE.

On reconnaîtra volontiers que dans le domaine mathématique, la possession d'une vérité importante ne devient complète et définitive qu'autant qu'on a réussi à l'établir par plus d'une méthode. À cet égard, la théorie des fonctions elliptiques offre un examplе célèbre, présent à tous les esprits, mais qui est loin d'être unique dans l'analyse. Je citerai encore le théorème de Sturm, resté comme enveloppé d'une sorte de mystère jusqu'à la mémorable découverte de M. Sylvester, qui a ouvert pour pénétrer au cœur de la question, une voie plus facile et plus féconde que celle du premier inventeur. Telles sont encore dans l'arithmétique supérieure, les lois de réciprocité entre deux nombres premiers auxquelles est attaché le nom à jamais illustre d'Eisenstein. Mais dans cette même science et pour des questions du plus haut intérêt, comme la détermination du nombre des classes de formes quadratiques de meme invariant, on a été moins heureux, et jusqu'ici le mérite de la première découverte est resté sans partage à Dirichlet. Enfin et pour en venir à l'objet de cette note, je citerai encore dans le champ de l'arithmétique, la proposition de Lambert sur l'irrationalité du rapport de la circonférence au diamètre, et des puissances de la base des logarithmes hyperboliques. Ayant été récemment conduit à m'occuper de ce dernier nombre, j'ai l'honneur de soumettre à la réunion de l'Association Britannique une démonstration nouvelle du théorème de Lambert, où n'intervient plus le calcul intégral, et qui, je l'espère, paraitra entièrement élémentaire. Je pars simplement de la série :

$$e^x = 1 + \frac{x}{1} + \frac{x^2}{1.2} + \dots + \frac{x^n}{1.2\dots n} + \dots,$$

et posant pour un instant :

$$F(x) = 1 + \frac{x}{1} + \frac{x^2}{1.2} + \dots + \frac{x^n}{1.2\dots n},$$

ce qui permet d'écrire :

$$\frac{e^x - F(x)}{x^{n+1}} = \frac{1}{1.2\dots n+1} + \frac{x}{1.2\dots n+2} + \dots = \sum \frac{x^k}{1.2\dots n+k+1},$$

il suffira comme on va voir, de prendre les dérivées d'ordre n des deux membres de cette relation. Effectivement, on obtient d'abord :

$$D_x^n \frac{e^x}{x^{n+1}} = \frac{e^x \Phi(x)}{x^{2n+1}},$$

où $\Phi(x)$ est un polynome à coefficients entiers du degré n, dont il n'est aucunement nécessaire d'avoir l'expression qu'il serait d'ailleurs aisé de former. Nous remarquerons ensuite, à l'égard du terme $\frac{F(x)}{x^{n+1}}$, que la differentiation effectuée n fois de suite, fait disparaître les dénominateurs des coefficients, de sorte qu'il vient :

$$D_x^n \frac{F(x)}{x^{n+1}} = \frac{\Phi_1(x)}{x^{2n+1}},$$

$\Phi_1(x)$ étant un polynome dont tous les coefficients sont des nombres entiers. De la relation proposée, nous tirons donc la suivante :

$$\frac{e^x \Phi(x) - \Phi_1(x)}{x^{2n+1}} = \sum_k^\infty \frac{(k+1)(k+2)\dots(k+n) x^k}{1.2\dots k+2n+1},$$

ou bien, sous une autre forme :

$$e^x\Phi(x)-\Phi_1(x)=x^{2n+1}\sum\frac{(k+1)(k+2)\ldots(k+n)x^k}{1.2\ldots\ldots k+2n+1}$$

$$=\frac{x^{2n+1}}{1.2\ldots n}\sum\frac{(k+1)(k+2)\ldots(k+n)x^k}{n+1.n+2\ldots k+2n+1}.$$

Or je dis qu'en faisant croitre n, le second membre, qui jamais ne peut s'évanouir, deviendra plus petit que toute grandeur donnée. Il en est effectivement ainsi du facteur $\frac{x^{2n+1}}{1.2\ldots n}$, et d'autre part, la série infinie $\sum\frac{(k+1)(k+2)\ldots(k+n)x^k}{n+1.n+2\ldots k+2n+1}$ étant mise sous la forme $\sum\frac{1.2\ldots\ldots k+n}{n+1.n+2\ldots k+2n+1}\cdot\frac{x^k}{1.2\ldots k}$, on reconnaît qu'elle a pour limite supérieure $e^x=\sum\frac{x^k}{1.2\ldots k}$, car le facteur $\frac{1.2\ldots\ldots k+n}{n+1.n+2\ldots k+2n+1}$ est inférieur à l'unité.

De là résulte qu'en supposant x un nombre entier, e^x ne peut être une quantité commensurable $\frac{b}{a}$; car on aurait

$$e^x\Phi(x)-\Phi_1(x)=\frac{b\Phi(x)-a\Phi_1(x)}{a},$$

et cette fraction dont le numérateur est essentiellement entier, d'après ce qui a été établi à l'égard des polynomes $\Phi(x)$ et $\Phi_1(x)$, ne peut sans être nulle, descendre au dessous de $\frac{1}{a}$.

L'expression découverte par Lambert: $\frac{e^x-e^{-x}}{e^x+e^{-x}}=\cfrac{x}{1+\cfrac{x^2}{3+\ldots}}$, que j'évite ainsi d'employer, n'en reste pas moins un résultat du plus grand prix et qui ouvre la voie à des recherches curieuses et intéressantes. En supposant par exemple $x=2$, on peut présumer qu'il restera quelque chose, de la série si simple des fractions intégrantes ayant pour numérateurs le nombre constant 4, dans la fraction continue ordinaire équivalente, dont les numérateurs seraient l'unité. En effet, il paraît que de distance en distance, viennent alors s'offrir des quotients incomplets continuellement croissants. C'est du moins ce qu'indique le résultat suivant, dû à M. G. Forestier, ingénieur des Ponts et Chaussées à Rochefort. Prenant l'expression que nous avons en vue, à partir du terme où les fractions intégrantes sont inférieures à $\frac{1}{2}$, c'est-à-dire la quantité

$$\cfrac{4}{9+\cfrac{4}{11+\cfrac{4}{13+\ddots}}}$$

M. Forestier a trouvé pour la fraction continue ordinaire équivalente

$$\cfrac{1}{q+\cfrac{1}{q'+\cfrac{1}{q''+\ddots}}}$$

la série suivante, des quotients incomplets, q, q', q'', etc., à savoir : 2, 2, 1, 20, 1, 10, 19, 1, 2, 11, 7, 1, 3, 1, 5, 1, 1, 1, 20, 3, 1, 3, 67, 2, 2, 3, 1, 5, 1, 3, 3, 147, ...

Or on y voit figurer les termes 19, 20, 67, 147, qui semblent justifier cette prévision.

On Modular Equations. *By* Professor HENRY J. STEPHEN SMITH, *F.R.S.*

On Triple Tangent Planes. *By* W. SPOTTISWOODE, *F.R.S.*

On the Calculation of Logarithms. *By the* Rev. HENRY WACE, *M.A., Brasenose College, Oxford, Chaplain of Lincoln's Inn.*

For the purpose of any further extension of our power of logarithmic computation, the author thinks attention should be recalled to the principle of the method proposed in 1845 by Mr. Weddle. An account of this method and of its history may be found in Mr. Peter Gray's preface to his 'Tables for the formation of Logarithms and Antilogarithms to twelve places,' published in 1865. It combines with great directness and simplicity the advantage of increasing in facility of application as the number of places is increased to which the computation is carried. It may be briefly described as a means for expressing all numbers, of whatever magnitude, in terms of certain factors to any required degree of accuracy. These factors are of the form $1 \pm \cdot 1^m.n$, where m is any integer and n any simple integer. When tabulated they present the following series:—

·9	·99	·999	·9999	·99999	
·8	·98	·998	·9998	·99998	
·7	·97	·997	·9997	·99997	
·6	·96	·996	·9996	·99996	
·5	·95	·995	·9995	·99995	&c. &c.
·4	·94	·994	·9994	·99994	
·3	·93	·993	·9993	·99993	
·2	·92	·992	·9992	·99992	
·1	·91	·991	·9991	·99991	

1·1	1·01	1·001	1·0001	
1·2	1·02	1·002	1·0002	
1·3	1·03	1·003	1·0003	
1·4	1·04	1·004	1·0004	
1·5	1·05	1·005	1·0005	&c. &c.
1·6	1·06	1·006	1·0006	
1·7	1·07	1·007	1·0007	
1·8	1·08	1·008	1·0008	
1·9	1·09	1·009	1·0009	

For convenience the author proposes to call these the Constituent Factors, and the former the negative, the latter the positive factors; and the tables of their logarithms may be called positive and negative Constituent Tables. To find the logarithms of numbers we use the negative table; to find antilogarithms, the positive table. A single example will show how numbers may be expressed in terms of the negative factors and of the integers up to 11.

A number on which Borda and Delambre have operated, viz. 543839, working to twelve places of decimals, may be taken as an example. Divide by 10^5 and 5, and the number becomes

$$1{\cdot}087678.$$

Our next object is to destroy the significant figure 8 in the second place of decimals. For this purpose multiply the number by $1 - \cdot 08$ or $\cdot 92$. This is the same thing as to subtract from the number eight times itself advanced two places; and the work is as follows:—

1·0	87 67	80	0
	87 01	42	4
1·0	00 66	37	6

By this multiplication we happen to have destroyed the third significant figure as well as the second. To destroy the fourth, multiply again by $1-\cdot0006$; in other words, subtract six times the number from itself four places in advance. We should next multiply by $1-\cdot00006$ and $1-\cdot000003$; and, after what has been said, the process will be intelligible without further explanation:

```
1·000|6 6 37|60 00 0
     |6 0 03|98 25 6
--------------------
1·000 0|6 3361|74 4
       |6 0003|80 2
--------------------
1·000 0 0|3357 94|2
         |3000 01 0
--------------------
1·000 0 0 0357 93 2
```

The next factor required would be $1-\cdot0000003$; but it is evident that multiplication by this factor would not affect the twelfth place of decimals, and consequently the last six significant figures thus obtained represent, without any further work, the remaining factors required.

It is thus shown that

$$543839\div10^5\div5\times\left(1-\frac{8}{10^2}\right)\times\left(1-\frac{6}{10^4}\right)\times\left(1-\frac{6}{10^5}\right)\times\left(1-\frac{3}{10^6}\right)\times\left(1-\frac{3}{10^7}\right)$$
$$\times\left(1-\frac{5}{10^8}\right)\times\left(1-\frac{7}{10^9}\right)\times\left(1-\frac{9}{10^{10}}\right)\times\left(1-\frac{3}{10^{11}}\right)\times\left(1-\frac{2}{10^{12}}\right)=1;$$

or that, to the requisite degree of accuracy, 543839 can be expressed as a fraction, the numerator of which is

$$10^5\times5,$$

and the denominator

$$\left(1-\frac{8}{10^2}\right)\left(1-\frac{6}{10^4}\right)\left(1-\frac{6}{10^5}\right)\left(1-\frac{3}{10^6}\right)\left(1-\frac{3}{10^7}\right)\left(1-\frac{5}{10^8}\right)$$
$$\times\left(1-\frac{7}{10^9}\right)\left(1-\frac{9}{10^{10}}\right)\left(1-\frac{3}{10^{11}}\right)\left(1-\frac{2}{10^{12}}\right).$$

The method of applying the positive table to find antilogarithms is better known, and need not here be explained.

It is further evident that we may by similar means express in terms of the negative factors the concluding figures of any number, or any decimal addition made to a given number. Thus, suppose we know the logarithms of 543 to 12 places, and wish to know that of 543·839, we operate on the latter number as follows:—

```
543|8 3 9|0 0 0|0 00|0 | × ·999
   |5 4 3|8 3 9|    |  |
---------------------------
543 2|9 5 1 6|1 0 00|0 | × ·999,5
    2|7 1 6 4|7 5 80|5 |
---------------------------
543 0 2|3 5 1 3 4|19 5 | × ·999,96
      2|1 7 2 0 9|40 5 |
---------------------------
543 0 0 1|7 9 2 4 79 0 | × ·999,997
        1|6 2 9 0 05|4 |
---------------------------
543 0 0 0 1|6 3 4 73 6 | × 3
          1|6 2 9 00 0 |
---------------------------
              5 7 3 6  | × ·0,1
              5 4 3 0  |
              ---------
                3 0 6  | × ·0,5
                2 7 2  |
                -------
                  3 4  | × 6
```

After working to half the number of figures, we proceed by simple division; and the multipliers corresponding to the successive quotients are

$$\cdot 999{,}999{,}7, \quad \cdot 999{,}999{,}999, \text{ \&c.}$$

This process may be regarded as a method of interpolation, and it appears to the author simpler and more direct than that of differences. It enables us, in short, by a direct operation to express differences in terms of a limited number of known factors.

The logarithms of these factors are determined with great facility from the fundamental series,

$$\log(1 \pm y) = \pm y - \tfrac{1}{2}y^2 \pm \tfrac{1}{3}y^3 - \tfrac{1}{4}y^4 \pm \text{ \&c};$$

for y being of the form $\cdot 1^m$, this series converges with great rapidity as m increases, so much so that for the latter half of the number of columns required in a constituent table only the first term of the series is required. Suppose, for instance, we are working to twenty places, then the hyperbolic logarithm of $1 - \cdot 1^{11} \times 7$ or of

$$\cdot 99999{,}99999{,}3 = -\cdot 00000{,}00000{,}7.$$

The determination of hyperbolic logarithms by this method is therefore peculiarly easy, the logarithms of the last half of the factors being written down for inspection without reference to the tables.

A fuller development of this method, embodying perhaps some improvement in its working, will be found in a paper contributed by the author to the 'Cambridge Messenger of Mathematics,' which will appear in the September and October Numbers of this year. The author has there furnished constituent tables for both hyperbolic and denary logarithms to twenty figures; and he has discussed the relation of the method to some modifications of it proposed by Mr. Gray and others. It would occupy too much space to enter here on these collateral points; but the author doss not think any modification of the method hitherto proposed retains its elasticity. It affords, at all events, a valuable means of calculating and testing isolated logarithms, and of extending partial tables of logarithms, such as are given in Callet, to a high number of figures. The principle, moreover, of reducing numbers to the form 1·0 .... or 1·00 .... might be employed to facilitate the printing of tables of ten or twelve figures. If the logarithms were tabulated of the integers up to 11 and of the numbers between 1 and 1·01 or 1·001, a short table of auxiliary constituent factors would furnish the logarithms of all other numbers by very simple calculations. Such a plan would probably be an improvement on that of the partial ten-figure tables published ten years ago by Pineto.

Mechanics and Physics.

On a Geometrical Solution of the following problem:—A quiescent rigid body possessing three degrees of freedom receives an impulse; determine the instantaneous screw about which the body commences to twist. By Robert Stawell Ball, *LL.D., F.R.S.*

I.

For an explanation of the language used, and for proof of several theorems, reference must be made to "Theory of Screws," Transactions of the Royal Irish Academy, vol. xxv. p. 157.

All the screws about which the body can be twisted form a coordinate-system; one screw of the coordinate-system can be found parallel to any given direction.

An ellipsoid can be found such that the radius vector, from the centre to the surface, is proportional to the twist velocity with which the body must twist about the parallel screw, so that its kinetic energy shall be one unit. This is the *ellipsoid of equal kinetic energy*.

Let s be the screw about which an impulsive wrench, F_s, constitutes the given impulse. All the screws belonging to the coordinate-system which are reciprocal

to s lie upon a cylindroid, the principal plane of which is called the *reciprocal plane*. Then the required instantaneous screw u is determined; for it is parallel to that diameter of the ellipsoid of equal kinetic energy which is conjugate to the reciprocal plane.

The demonstration is as follows:—Any three conjugate diameters of the ellipsoid of equal kinetic energy are parallel to three screws of the system, which are *conjugate screws of kinetic energy*. The property possessed by three conjugate screws of kinetic energy A, B, C, is that if A′, B′, C′ be three impulsive screws corresponding respectively to A, B, C as instantaneous screws, then A′ is reciprocal to B and C, B′ is reciprocal to A and C, C′ is reciprocal to A and B.

If u be one of three conjugate screws of kinetic energy, the two others must be parallel to the reciprocal plane, and therefore reciprocal to s. Hence an impulsive wrench about s must make the body commence to twist about u.

II.

The same construction may be arrived at in a different manner.

Let q be the screw of the coordinate-system which is normal to the plane reciprocal to s.

Let $F_s=\frac{MV_s}{t}$ be the impulsive wrench which acts about s for the infinitely small time t.

Let ω_q be the twist velocity with which a body must twist uniformly round q in order to do one unit of work against F_s in the time t.

Draw a plane parallel to the reciprocal plane at a distance ω_q from the kinematic centre.

Draw the cone from the kinematic centre to the intersection of this plane with the ellipsoid of equal kinetic energy.

Then all the screws of the coordinate-system which are parallel to the generators of this cone possess the following property:—That if the body be constrained to twist about any one of these screws it will, in consequence of the impulsive wrench F_s, move off from rest with the unit of kinetic energy.

The screw s being given, F_s will vary inversely as ω_q; consequently when the plane touches the ellipsoid, and when the cone has shrunk to one right line, a smaller impulse about s will give the body the unit of kinetic energy about the screw of the system parallel to that line, than if the body had been constrained about any other screw of the system.

Applying Euler's theorem, that a body will always move off with the maximum kinetic energy, we arrive at the construction already given.

III.

Conversely, given the instantaneous screw u, about which the body will commence to twist, selected from the general coordinate-system with three degrees of freedom, determine the corresponding impulsive screw s.

This problem is really indeterminate; the conditions to be fulfilled by s are thus proved. Draw the plane in the ellipsoid of equal kinetic energy, conjugate to the direction of u. Construct the cylindroid of screws belonging to the system which are parallel to this plane, then s may be any screw reciprocal to this cylindroid. For example, through any point a cone of screws can be drawn, any one of which, as an impulsive screw, corresponds to u as an instantaneous screw.

Contributions to the Theory of Screws.

By Robert Stawell Ball, *LL.D., F.R.S.*

1. *Coordinates of a Screw.*—Six screws, each of which is reciprocal to the remaining five, are called a group of coreciprocals*. If the unit twist velocity about

* A group of six coreciprocals is intimately connected with the group of six fundamental complexes already introduced into geometry by Dr. Felix Klein (see 'Math. Ann.' Band ii. p. 203).

a screw a be decomposed into six components, α_1, &c., a_6, about the coreciprocals, then α_1, &c., a_6, are the coordinates of a.

The pitch of a is

$$\Sigma'_6 p_\kappa a_\kappa^2,$$

where p_1, &c., p_6, are the pitches of the coreciprocals.

The condition that two screws a, β are reciprocal is

$$\Sigma'_6 p_\kappa a_\kappa \beta_\kappa = 0.$$

2. *Impulsive and instantaneous Screws.*—By proper selection of the coreciprocal group the relation between an impulsive screw and the corresponding instantaneous screw is very simple. If α_1, &c., a_6, be an instantaneous screw, then $p_1\alpha_1$, &c., $p_6 a_6$, is the corresponding impulsive screw. Two of the coreciprocals are directed along each of the principal axes through the centre of inertia of the rigid body; and the corresponding pitches are $+$ and $-$ the radius of gyration.

3. *Conjugate Screws of Kinetic energy.*—If

$$\Sigma'_6 p_\kappa^2 a_\kappa \beta_\kappa = 0,$$

then the impulsive screw corresponding to a is reciprocal to β; but precisely the same condition expresses that the impulsive screw corresponding to β is reciprocal to a.

On the Kinematics of a Rigid Body.* *By* Professor J. D. EVERETT, *F.R.S.E.*

The object of the paper is the investigation of the instantaneous movement of a rigid body (having no point fixed). Such investigation has usually been confined to properties depending on the consideration of two consecutive positions; and the investigation is here extended to properties depending on three, and in the case of motion in one plane to four and five consecutive positions.

The most general motion of a rigid body may, as is well known, be represented by a succession of small screwings about successive lines called central axes; and these successive central axes generate two ruled surfaces—one in the body, and the other in space—these two surfaces being perfectly determinate in the case of any given motion.

Two cones of determinate shape can be constructed by drawing through an arbitrary point of the body lines parallel to the successive central axes in the body, and by drawing through an arbitrary point of space lines parallel to the successive central axes in space. It is shown in this paper that the most general motion of a rigid body can be represented by giving to the cone in space a motion of pure translation, and causing the cone in the body to roll upon the cone thus translated.

Expressions are obtained for the curvatures of the two cones corresponding to a given instantaneous motion, the data being derived from the consideration of four consecutive positions of the body. When only three consecutive positions are given, the curvatures of the two cones are indeterminate, being merely connected by one equation of condition. Hence, so far as regards properties depending on three consecutive positions, the instantaneous motion of a rigid body can always be represented by the rolling of a right circular cone in the body upon a plane which has a movement of translation in space. In this representation the curvature of the circular cone is determinate, but its vertex is an arbitrary particle of the body.

The locus of those particles which at the instant considered have straight motion, is investigated, and is found to be in general a cubic curve.

The curvatures of the two ruled surfaces at points on their respective lines of striction are investigated; and it is shown that the tangent plane to either of the ruled surfaces at a point on the line of striction is perpendicular to the corresponding tangent plane of the cone. The forms of the two ruled surfaces, at points very

* The paper will appear in full in the 'Quarterly Journal of Mathematics' for 1874.

distant from the lines of striction, are investigated and shown to be ultimately identical with the forms of the two cones.

The condition of intersection of successive central axes is investigated; and expressions are obtained for the curvatures of the two cuspidal edges which are then generated, one in the body and the other in space.

Throughout this investigation the motion is supposed to be specified with reference to rectangular axes fixed in space—the specifying elements being the three component velocities of translation, the three component velocities of rotation, and the differential coefficients of these six velocities with respect to time.

The latter portion of the paper deals with motion in two dimensions. It is shown that, in the most general motion of a plane rigid figure in its own plane, the locus of points which at a given instant have straight motion is a circle traversing the instantaneous centre; but one singular point on this circle is to be excepted from the locus, namely the instantaneous centre itself, which, instead of being (like other points on the circle) at a point of inflection of its path, is at a cusp, and is moving with infinite curvature, whereas all other points on the circle are moving with zero curvature. This startling result is confirmed by a comparison of the cycloid with the trochoid. When a circle rolls along a straight line, a point just within the circumference describes a trochoid having two points of inflection very near together, and the short connecting arc has a total curvatnre of nearly 180°; whereas in the case of a point on the circumference, these features are replaced by a cusp.

The instantaneous curvatures of the paths traced by the particles of a moving figure depend on three consecutive positions only. Four consecutive positions of the figure are sufficient to determine two consecutive "circles of straight motion." Those two particles of the body which are situated at the intersections of these two circles might at first sight be deemed to be points of double straight motion—that is, to have straight motion for two consecutive instants; but on examination it turns out that one of these two points is not a point of straight motion at all, being, in fact, the singular point above mentioned. There is therefore in general only one point of double straight motion. The position of this point is investigated in the general case of one circle rolling on another, and its connexion with the subject of "apparently neutral" equilibrium of a heavy body is pointed out.

On certain connexions between the Molecular Properties of Metals. By Professor G. Forbes.

On the Final State of a System of Molecules in Motion subject to Forces of any kind. By J. Clerk Maxwell.

Since reading Principal Guthrie's first letter on this subject ('Nature,' May 22, 1873), I have thought of several ways of investigating the equilibrium of temperature in a gas acted on by gravity. One of these is to investigate the condition of the column as to density when the temperature is constant, and to show that when this is fulfilled the column also fulfils the condition that there shall be no upward or downward transmission of energy, or, in fact, of any other function of the masses and velocities of the molecules. But a far more direct and general method was suggested to me by the investigation of Dr. Ludwig Boltzmann* on the final distribution of energy in a finite system of elastic bodies; and the following is a sketch of this method as applied to the simpler case of a number of molecules so great that it may be treated as infinite.

Principal Guthrie's second letter is especially valuable as stating his case in the form of distinct propositions, every one of which, except the fifth, is incontrovertible. He has himself pointed out that it is here that we differ, and that this difference may ultimately be traced to a difference in our doctrines as to the distri-

* Studien über das Gleichgewicht der lebendigen Kraft zwischen bewegten materiellen Punkten, von Dr. Ludwig Boltzmann. Sitzb. d. Akad. d. Wissensch. October 8, 1863 (Vienna).

bution of velocity among the molecules of any given portion of the gas. He assumes, as Clausius (at least in his earlier investigations) did, that the velocities of all the molecules are equal, whereas I hold, as I first stated in the Philosophical Magazine for January 1860, that they are distributed according to the same law as errors of observation are distributed according to the received theory of such errors. It is easy to show that if the velocities are all equal at any instant they will become unequal as soon as encounters of any kind, whether collisions or "perihelion passages," take place. The demonstration of the actual law of distribution was given by me in an improved form in my paper on the "Dynamical Theory of Gases," Phil. Trans. 1866, and Phil. Mag. 1867; and the far more elaborate investigation of Boltzmann has led him to the same result. I am greatly indebted to Boltzmann for the method used in the latter part of the following sketch of the general investigation.

Let perfectly elastic molecules of different kinds be in motion within a vessel with perfectly elastic sides, and let each kind of molecules be acted on by forces which have a potential the form of which may be different for different kinds of molecules.

Let x, y, z, be the coordinates of a molecule, M, and ξ, η, ζ the components of its velocity, and let it be required to determine the number of molecules of a given kind which, on an average, have their coordinates between x and $x+dx$, y and $y+dy$, z and $z+dz$, and also their component velocities between ξ and $\xi+d\xi$, η and $\eta+d\eta$, and ζ and $\zeta+d\zeta$. This number must depend on the coordinates and the components of velocities and on the differences of the limits of these quantities. We may therefore write it

$$dN=f(x, y, z, \xi, \eta, \zeta)\, dx\, dy\, dz\, d\xi\, d\eta\, d\zeta. \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

We shall begin by investigating the manner in which this quantity depends on the components of velocity, before we proceed to determine in what way it depends on the coordinates.

If we distinguish by suffixes the quantities corresponding to different kinds of molecules, the whole number of molecules of the first and second kind within a given space, which have velocities within given limits, may be written

$$f_1\,(\xi_1, \eta_1, \zeta_1)\, d\xi_1, d\eta_1, d\zeta_1=n_1, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and

$$f_2\,(\xi_2, \eta_2, \zeta_2)\, d\xi_2, d\eta_2, d\zeta_2=n_2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The number of pairs which can be formed by taking one molecule of each kind is $n_1\, n_2$.

Let a pair of molecules encounter each other, and after the encounter let their component velocities be $\xi_1', \eta_1', \zeta_1'$ and $\xi_2', \eta_2', \zeta_2'$. The nature of the encounter is completely defined when we know $\xi_2-\xi_1, \eta_2-\eta_1, \zeta_2-\zeta_1$ the velocity of the second molecule relative to the first before the encounter, and $x_2-x_1, y_2-y_1, z_2-z_1$ the position of the centre of the second molecule relative to the first at the instant of the encounter. When these quantities are given, $\xi_2'-\xi_1', \eta_2'-\eta_1'$, and $\zeta_2'-\zeta_1'$, the components of the relative velocity after the encounter, are determinable.

Hence, putting α, β, γ for these relative velocities, and a, b, c for the relative positions, we find for the number of molecules of the first kind having velocities between the limits ξ_1 and $\xi_1+d\xi$, &c., which encounter molecules of the second kind having velocities between the limits ξ_2 and $\xi_2+d\xi$, &c., in such a way that the relative velocities lie between α and $\alpha+d\alpha$, &c., and the relative positions between a and $a+da$, &c.

$$f_1\,(\xi_1\, \eta_1, \zeta_1)\, d\xi\, d\eta\, d\zeta \,.\, f_2\,(\xi_2, \eta_2, \zeta_2)\, d\xi\, d\eta\, d\zeta \,.\, \phi\,(abc\,\alpha\beta\gamma)\, da\, db\, dc\, d\alpha\, d\beta\, d\gamma\,; \;. \quad (4)$$

and after the encounter the velocity of M_1 will be between the limits ξ_1' and $\xi_1'+d\xi$, &c., and that of M_2 between the limits ξ_2' and $\xi_2'+d\xi$, &c.

The differences of the limits of velocity are equal for both kinds of molecules, and that both before and after the encounter.

When the state of motion of the system is in its permanent condition, as many pairs of molecules must change their velocities from V_1, V_2 to V_1', V_2' as from

V_1', V_2' to V_1, V_2; and the circumstances of the encounter in the one case are precisely similar to those in the second. Hence, omitting for the sake of brevity the quantities $d\xi$ &c., and ϕ, which have the same values in the two cases, we find

$$f_1(\xi_1, \eta_1, \zeta_1) f_2(\xi_2, \eta_2, \zeta_2) = f_1(\xi'_1, \eta'_1, \zeta'_1) f_2(\xi'_2, \eta'_2, \zeta'_2). \quad . \quad . \quad . \quad (5)$$

If we now write

$$\log f(\xi, \eta, \zeta) = F(MV^2, l, m, n), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where l, m, n are the direction cosines of the velocity V of the molecule M, taking the logarithm of both sides of equation (5),

$$F_1(M_1V_1^2 l_1 m_1 n_1) + F_2(M_2V_2^2 l_2 m_2 n_2) = F_1(M_1V_1'^2 l'_1 m'_1 n'_1) + F_2(M_2V_2'^2 l'_2 m'_2 n'_2). \quad (7)$$

The only necessary relation between the variables before and after the encounter is

$$M_1V_1^2 + M_2V_2^2 = M_1V_1'^2 + M_2V_2'^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

If the right-hand sides of the equations (7) and (8) are constant, the left-hand sides will also be constant; and since l_1, m_1, n_1 are independent of l_2, m_2, n_2, we must have

$$F_1 = -AM_1V_1^2 \text{ and } F_2 = -AM_2V_2^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where A is a quantity independent of the components of velocity, or

$$f_1(\xi_1, \eta_1, \zeta_1) = C_1 e^{-AM_1V_1^2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$f_2(\xi_2, \eta_2, \zeta_2) = C_2 e^{-AM_2V_2^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

This result as to the distribution of the velocities of the molecules at a given place is independent of the action of finite forces on the molecules during their encounter; for such forces do not affect the velocities during the infinitely short time of the encounter.

We may therefore write equation (1)

$$dN = Ce^{-AM(\xi^2+\eta^2+\zeta^2)} d\xi\, d\eta\, d\zeta\, dx\, dy\, dz, \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where C is a function of xyz, which may be different for different kinds of molecules, while A is the same for every kind of molecule, though it may, for aught we know as yet, vary from one place to another.

Let us now suppose that the kind of molecules under consideration are acted on by a force whose potential is ψ. The variations of xyz arising from the motion of the molecules during a time δt are

$$\delta x = \xi \delta t, \; \delta y = \eta \delta t, \; \delta z = \zeta \delta t; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

and those of ξ, η, ζ in the same time due to the action of the force, are

$$\delta\xi = -\frac{d\psi}{dx}\delta t, \; \delta\eta = -\frac{d\psi}{dy}\delta t, \; \delta\zeta = -\frac{d\psi}{dz}\delta t. \quad . \quad . \quad . \quad . \quad (14)$$

If we put

$$c = \log C, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$$\log \frac{dN}{d\xi\, d\eta\, d\zeta\, dx\, dy\, dz} = c - AM(\xi^2+\eta^2+\zeta^2). \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

The variation of this quantity due to the variations δx_1, δy_1, δz_1, $\delta\xi_1$, $\delta\eta_1$, $\delta\zeta_1$ is

$$\left.\begin{array}{r} \left(\xi\dfrac{dc}{dx} + \eta\dfrac{dc}{dy} + \zeta\dfrac{dc}{dz}\right)\delta t \\ 2AM\left(\xi\dfrac{d\psi}{dx} + \eta\dfrac{d\psi}{dy} + \zeta\dfrac{d\psi}{dz}\right)\delta t \\ -M(\xi^2+\eta^2+\zeta^2)\left(\xi\dfrac{dA}{dx} + \eta\dfrac{dA}{dy} + \zeta\dfrac{dA}{dz}\right)\delta t. \end{array}\right\} \quad . \quad . \quad . \quad (17)$$

Since the number of the molecules does not vary during their motion, this quantity is zero, whatever the values of ξ, η, ζ. Hence we have in virtue of the last term,

$$\frac{dA}{dx}=0, \quad \frac{dA}{dy}=0, \quad \frac{dA}{dz}=0, \quad \ldots\ldots\ldots \quad (18)$$

or A is constant throughout the whole region traversed by the molecules.

Next, comparing the first and second terms, we find.

$$c=-2AM(\psi+B). \quad \ldots\ldots\ldots \quad (19)$$

We thus obtain as the complete form of dN,

$$dN_1=e^{-(AM_1(\xi_1^2+\eta_1^2+\zeta_1^2+2\psi_1+B_1)}dx\,dy\,dz\,d\xi\,d\eta\,d\zeta, \quad \ldots \quad (20)$$

where A is an absolute constant, the same for every kind of molecule in the vessel, but B_1 belongs to the first kind only. To determine these constants, we must integrate this quantity with respect to the six variables, and equate the result to the number of molecules of the first kind. We must then, by integrating

$$dN_1\tfrac{1}{2}M_1(\xi_1^2+\eta_1^2+\zeta^2+2\psi_1),$$

determine the whole energy of the system, and equate it to the original energy. We shall thus obtain a sufficient number of equations to determine the constant A, common to all the molecules, and B_1, B_2, &c., those belonging to each kind.

The value of A determines that of the mean kinetic energy of all the molecules in a given place, which is $\frac{3}{2}\frac{1}{A}$; and therefore, according to the kinetic theory, it also determines the temperature of the medium at that place. Hence, since A_1, in the permanent state of the system, is the same for every part of the system, it follows that the temperature is everywhere the same, whatever forces act upon the molecules.

The number of molecules of the first kind in the element $dz\,dy\,dz$,

$$\left(\frac{\pi}{A}\right)^{\frac{3}{2}} e^{-AM_1(2\psi_1+B_1)}dx\,dy\,dz. \quad \ldots\ldots\ldots \quad (21)$$

The effect of the force whose potential is ψ_1 is therefore to cause the molecules of the first kind to accumulate in greater numbers in those parts of the vessel towards which the force acts; and the distribution of each different kind of molecules in the vessel is determined by the forces which act on them in the same way as if no other molecules were present. This agrees with Dalton's doctrine of the distribution of mixed gases.

On the Axis of least Moments in a Rectangular Beam. By John Neville.

On certain Phenomena of Impact. By Professor Osborne Reynolds.

On Æthereal Friction. By Professor Balfour Stewart, *LL.D., F.R.S.*

Prof. J. C. Maxwell has made a series of experiments on the friction of gases. In these experiments a horizontal disk was made to oscillate in an imperfect vacuum near a similar disk at rest, and it was found that the motion of the oscillating disk was carried away by the residual gas of the vacuum at a rate depending on the chemical character of the gas, and depending also upon its temperature, but nevertheless independent of its density.

While the temperature of the arrangement remained constant, it was found by Prof. Maxwell that this fluid friction was rather greater for atmospheric air than for carbonic acid, while for hydrogen it was about half as great as for air.

On the other hand, when the temperatures were made to vary, the result was found to be proportional to the absolute temperature.

These experiments do not show that there is no such thing as æthereal friction—that is to say, friction from something which fills all space and is independent of air; but we may argue from them that such an æthereal friction must either have been nearly insensible in these experiments, or it must, as well as the friction from the gas, have varied with the absolute temperatures, in which case the two frictions would not be separable from one another by the method of the experiment.

Prof. Tait and myself have made some experiments upon the heating of a disk by rapid rotation *in vacuo*. In these experiments we found a mere surface-heating due to air, which varied not only with the quality but also with the quantity of the residual gas; and we also found a surface-effect (more deeply seated, however, than the former) which appeared to be a residual effect, and which it is possible may be due to æthereal friction. We made no experiments at varying temperatures; but we made use of various residual gases, and found that the heating-effect for carbonic acid was perhaps a trifle less than for air, while that for hydrogen appeared to be about four times less than that for air. Now, comparing Prof. Maxwell's experiments with ours, we have in the former a stoppage of motion, which is rather less for carbonic acid than for air, and about half as large for hydrogen as for air. In the latter, again, we have a heating-effect rather less for carbonic acid than for air, and only about one fourth as large for hydrogen as for air. Thus it appears that the stopping effect of hydrogen in Prof. Maxwell's experiments is relatively greater in comparison with air than is its heating-effect in our experiments when compared with that of air. The effects of these various gases would bear to one another more nearly the same proportion in both experiments if we might suppose that in Prof. Maxwell's experiments there was mixed up with gaseous friction a very sensible æthereal friction; but in that case it would be necessary to suppose that the æthereal friction was proportional to the absolute temperature.

During the Meeting of the British Association at Edinburgh, I brought before the Association reasons for imagining that if we have a body in visible motion in an enclosure of constant temperature the visible motion of the body will gradually be changed into heat. The nature of the argument was such as to render it probable (although not absolutely certain) that in such a case the rapidity of conversion will be greater the higher the temperature of the enclosure.

I will now refer to some experiments of Prof. Tait, which formed the subject of the last Rede Lecture. These experiments were suggested to Prof. Tait by an hypothesis derived from the theory of the dissipation of energy, which led him to think that the resistance of a substance to the conduction of electricity, and also of heat, would be found proportional to the absolute temperature. Matthiessen and Von Bose in the case of electricity, and Principal Forbes in the case of heat, had already proved that, as a matter of fact, the law was not very different from that imagined by Prof. Tait. The result of these experiments has been to confirm the truth of this law.

The following considerations, also connected with the dissipation of energy, point to the same conclusion. Perhaps we may regard the æthereal medium as that medium whose office it is to degrade all directed motion and ultimately convert it into universally diffused heat, and in virtue of which all the visible differential motion of the universe will ultimately be destroyed by some process analogous to friction.

Now in order to imagine the way in which æther may possibly act in bringing about this result, let us imagine some familiar instance of directed motion, as, for instance, a railway-train in motion. The train, let us suppose, and the air in it, are both in rapid motion, while the air outside is at rest. Now as the train proceeds, suppose that a series of cannons loaded with blank cartridges are fired towards the train. A series of violent sounds will go in at the one window and out at the other of each carriage. Each sound will push some air from the stratum of air at rest into the carriage on the one side, and it will push some air from the carriage into the stratum at rest on the other side. Now in this operation it would seem that part of the visible motion of the train must be taken from it. To make a comparison, it is as if a series of individuals were jumping into the train at the

one side and out of it at the other, the result being that each carries away so much of the motion of the train, and therefore renders it difficult for the engine to drive the train. Each individual comes to the ground with an immense forward impetus and rubs along the ground till this is lost, in fact he carries with him so much motion of the train and converts it into heat by friction against the ground.

Now something similar to this must happen to a substance in visible motion in an enclosure of constant temperature. The rays of light and heat will play very much the same part as the waves of sound, or as the crowd of people in the above illustration, at least if we except those which fall perpendicularly upon the surface of the moving body. The moving body is like the train, and the rays of light and heat are similar to individuals entering the train from a stratum of æther at rest, and leaving the train into a stratum of æther at rest again, each probably transmuting into heat a certain small portion of the visible motion of the train as it were by a species of friction. Of course the intensity of such an influence would depend upon the intensity of the rays of light and heat. Now it matters not what the particular kind of motion be which constitutes this train, and we may assert that all directed motion will suffer from such a cause, and possibly according to the same laws. Visible motion, such as that of a rotating disk or of a meteor is of course one form of such motion; but a current of electricity or of heat may equally represent some form of directed motion. In fine we may perhaps suppose that all forms of directed motion are resisted by this peculiar influence, which evidently depends upon what we may term the temperature of the æther, or at least upon the intensity of those vibrations which the æther transmits.

Astronomy.

On the Importance and Necessity of continued Systematic Observations on the Moon's Surface. By W. R. Birt, *F.R.A.S.*

Note on the Proper Motions of Nebulæ. By William Huggins, *D.C.L., LL.D., F.R.S.*

There are three kinds of motion which we may expect to exist in a nebula, which, if sufficiently rapid, might be detected by the spectroscope:—

1. A motion of rotation in the case of the planetary nebulæ, which might be discovered by placing the slit of the spectroscope on opposite limbs of the nebula.
2. A motion of translation in the visual direction of some portions of the nebulous matter within the nebula. Such motion might possibly be detected by comparing, in a spectroscope of sufficient dispersive power, the spectra of different parts of a large nebula such as that in Orion.
3. A motion of translation in space of the nebula in the line of sight.

The observations to be described were undertaken with the view of searching for this last kind of motion, namely that of the whole nebula in the line of sight. For this purpose it is necessary to compare the lines of the nebula with those of a terrestrial substance which has been found to be in the nebula. Now the coincidence of the third and fourth line of the nebular spectrum with lines of hydrogen was available in the case of a few only of the brightest nebulæ.

I had found that the apparent coincidence of the brightest line of the nebulæ with the brightest line in the spectrum of nitrogen was not maintained when a more powerful spectroscope was used. The nebular line was then seen to be thin and defined, while the line of nitrogen appeared double and each of its components nebulous at the edges. The thin line of the nebula coincides very nearly with the less refrangible of the two lines forming the double line of nitrogen.

Fortunately I found a line which appears under some conditions of the spark in the spectrum of lead, which is single, defined, and occurs exactly at that part of the spectrum. This line is represented in Thalén's map by a short line, to indicate

that under ordinary conditions of the spark, when the characteristic lines of lead are strong, this line is seen only in the part of the metal vapour which is close to the electrode. I found, however, that under other conditions of the electric discharge this line extends across the spectrum, and becomes bright, at the same time that the principal lines of the lead-spectrum are very faint.

A simultaneous comparison of this line with the brightest of the lines of the nebulæ showed that, if not truly coincident, it was sufficiently so, under the powers of dispersion which can be applied to the nebulæ, to serve as a fiducial line of comparison in the observations which I had in view.

I need not say that the coincidence of the lines does not indicate the presence of lead in the nebula.

I found that in the spectrum of the great nebula in Orion, at the same time that the third line was seen to be coincident with Hβ, the first line appeared to coincide with the line in the spectrum of lead. There was a very slight apparent excess of breadth in the nebular line, due possibly to its being in a small degree the brighter of the two, which appeared to extend towards the red, so that the more refrangible sides of the lines were in a right line.

The lead line could now be used as a fiducial line for the examination of the motion of the nebulæ which are too faint to permit of direct comparison with hydrogen.

By this method the following nebulæ have been carefully examined. In all these nebulæ the relative position of the first nebular line with the lead line was found to be exactly the same in a spectroscope containing two compound prisms which together give a dispersion about equal to that of four single prisms of dense flint of 60°.

The results, though negative, are, however, not without interest, as they show that these nebulæ were not moving toward or from the earth with a velocity so great as thirty miles per second.

List of Nebulæ.

	h.	H.	
No. 1179,	360.		M. 42.
No. 4234.	1970.		Σ. 5.
No. 4373.		IV. 37.	
No. 4390.	2000.		Σ. 6.
No. 4447.	2073.		M. 57.
No. 4510.	2047.	IV. 51.	
No. 4964.	2241.	IV. 18.	

The numbers in the above list are from Sir J. Herschel's 'General Catalogue of Nebulæ.'

On the Application of Photography to show the passage of Venus across the Sun's Disk. By M. Janssen.

Results of some recent Solar Investigations. By J. Norman Lockyer, *F.R.S.*

On the Visibility of the Dark side of the Planet Venus. By Professor A. Schafarik, *Prague.*

[Ordered to be printed *in extenso* among the Reports.]

LIGHT.

Experiments on Light with circularly ruled plates of Glass. By PHILIP BRAHAM, *F.C.S.*

A point of light, viewed at a distance through plates of glass with concentric circles ruled thereon, is seen to be surrounded by rings of brilliant colours. The author tried the experiment of introducing the ruled glass into a beam of sunlight $\frac{1}{2}$ an inch in diameter, and viewing the rings on a screen placed 10 feet from the ruled plate, with the following results:—

With 2500 lines to the inch there appear two rings of colour, the diameters of the red rings (which are always outward) being 1 foot 5 inches and 2 feet 10 inches, the width of the rings from the outside of the red to the inside of the violet in each case being respectively $3\frac{1}{2}$ inches and $6\frac{1}{4}$ inches.

With 3500, 1 foot 8 inches and 3 feet 3 inches, width $4\frac{1}{4}''$ and $8''$.

With 5000, only one ring 3 feet in diameter, width $8''$.

With 10,000, one ring 5 feet in diameter, width $11''$.

There are other rings visible, but they are faint and indefinite.

The coloured rings are also seen by reflection from the outer glass, with the same angular dispersion.

On some Abnormal Effects of Binocular Vision. By W. S. DAVIS.

While using a Herapath blowpipe a short time since, and having my eyes fixed intently on a bead held in the flame, I was suddenly startled by seeing the papered wall, which was about three feet in front of me, make its appearance close up to the point of the flame, the patterns of the paper being at the same time much diminished in size. Casting my eyes from side to side, and upwards and downwards, the appearance still remained as distinct as in ordinary sight; on moving my eyes beyond the boundary of the wall the appearance immediately vanished. I afterwards succeeded in reproducing the appearance by simply looking at the wall and converging the optic axes of my eyes.

It occurred to me that the phenomenon I had seen was due to the *crossing* of the optic axes of my eyes, the angle being such that each eye received the impression of a precisely similar figure. Under these circumstances a single figure would be seen, as when a single flat object is viewed with both eyes in ordinary sight. In order to satisfy myself that this was the correct explanation I made a geometrical construction, traced the relations which should hold, and verified them by actual measurements.

Continuing my experiments, I succeeded by a further convergence of the optic axes to combine alternate patterns, and pairs still more widely separated, up to twelve or more. It is a very interesting experiment to combine a given pattern with, say, the fifth or sixth from it, and then by a peculiar effort, more easily made than described, to let one pattern slip at a time, the wall retreating by steps as each pattern is slipped.

On one occasion, when I had combined two patterns at some distance apart, I happened to shut one eye, when, to my surprise, the combinational figure remained as distinct and at the same distance as before. I can only account for this by supposing that the muscles of the eye which was closed were still acting in sympathy with those of the open eye; and subsequent experiments favoured this view.

The results of the foregoing experiments led me to think that it would be possible to optically combine two patterns without crossing the optic axes, provided the distance between the centres of the patterns was not greater than that between the centres of the eyes. This I succeeded in doing, and the result was very remarkable: the wall appeared to retreat and take up a fixed position at some distance beyond its actual position; on looking slowly upwards and sideways along the wall the dimensions of the room appeared to be enormously increased, while on looking downwards I appeared to be perched on a sort of gallery, the wall appearing to be several yards from me, and descending many yards below the floor on which I was standing. This appearance was as vivid and distinct as in the case of ordinary vision.

With patterns on a horizontal surface, such as a carpet, the results were very curious. On combining pairs of patterns with the optic axes crossed, I appeared to be standing in a hole with the level of the floor up to my waist, while on combining pairs of patterns with the optic axes uncrossed, I was apparently standing on a pedestal with the widely expanded floor far below me; and so strong was the delusion, that I could scarcely venture to move for fear of falling over.

Colours I found could be fairly well combined by painting two patterns different colours and then causing the two to coalesce, with or without crossing the optic axes.

I have also succeeded in combining two solid bodies of the same size and shape, but of different colour, both with the optic axes crossed and with them uncrossed. Perhaps one of the most curious experiments I have made of this kind is to optically combine the heads of two persons, thereby producing a combinational figure of the two.

On a Refraction-Spectrum without a Prism. *By* Professor J. D. Everett, *F.R.S.E.*

It was pointed out by Wollaston in the Philosophical Transactions for 1800, that triple images can be obtained by looking at real objects through the stratum of intermixture of two liquids of different refractive powers, one of which has been gently poured on the top of the other.

Having set up an arrangement of this kind last spring, in a cubical vessel (measuring 6 inches each way) with plate-glass sides, a strong solution of common salt being the lower liquid and pure water the upper, I observed such decided colour-effects, that the idea occurred to me of trying whether a spectrum could be obtained. I accordingly placed the vessel of liquid on a high stool in the centre of a dark room, and looked through the stratum of intermixture at a horizontal slit in the window-shutter, which was about 10 feet distant, and was below the level of the said stratum. The following were some of the phenomena observed, about a week having elapsed since the liquids were placed in the vessel. When the eye was at any distance less than about 3 feet from the vessel, one image of the slit was seen. It was highly coloured, forming a very impure spectrum, with blue above and red below. Its apparent position was above the real slit, and at about the same distance from the observer.

When the eye was at a distance of $3\frac{1}{2}$ feet or upwards from the vessel, three images of the slit were visible. At some distances they could all be seen at once. At other distances two could be seen at once, and the third came into view on raising or lowering the eye. All three of them were above the true direction of the slit, and all were highly coloured. The highest and the lowest were virtual images, and were almost precisely alike and similar to the single image above described. They were erect images, and had accordingly blue above and red below. Between them, when the eye was at a proper height, was seen another image with more colour than either, and with the colours in inverted order, that is to say, with red above and blue below. It was in fact a real and inverted image, formed at the distance of about 3 feet from the vessel; and a screen held there received the image in the form of a horizontal line of light with coloured edges, the action of the liquid being somewhat similar to that of a cylindrical lens. All the images were very impure in colour, being nearly white in their central portions.

The colours were improved by lowering the eye so as to make the middle image move up to the highest. Red was the first colour that appeared at the junction; and it showed extremely well. Violet (or when the light was feeble, blue) was the last colour that was seen before both images became extinct by the descent of the observer's eye.

The largest sheets of colour were seen when the eye was exactly at the place where the real image was formed. It was easy to obtain a long vertical strip of blue by holding the eye at the distance of about 3 feet, and a long vertical strip of red by holding the eye at the distance of about 4 feet. A long vertical strip of rich yellow could be obtained at an intermediate distance.

The experiment was varied by holding close in front of the eye a card with a

fine horizontal slit, the observer of course looking through the slit; and in some of the observations this card was fixed in an adjustable stand, and the slit brought into coincidence with the real image before looking through. The red and blue were not much altered by the introduction of the card; but yellow could with difficulty be obtained, the yellow previously obtained having in fact been a highly composite colour.

The apparatus was left to itself for several days; and its focal length was found to be continually increasing; that is to say, the real image receded further and further from the vessel, the average recess (estimated very roughly) being about a foot per day, till it reached the wall, which was 10 feet distant.

The experiment was repeated, first with solution of sugar of lead, and secondly with solution of alum, in place of solution of salt; but the original experiment gave the finest displays of colour.

There is no difficulty in explaining the phenomena above described. They are mainly due to the bending of rays towards that side on which the index of refraction is greatest (which in the above instances is the lower side), and to the fact that this bending is greatest for the rays of shortest wave-length. The magnitude, however, of the chromatic effect is very startling; and I am not aware that any such results have been previously recorded.

Possibly the increase of focal length in such an arrangement as is above described may be found to furnish a convenient test of the rapidity of liquid diffusion.

On Irradiation. *By* Professor G. FORBES.

Photographs of Fluorescent Substances. *Exhibited by* Dr. GLADSTONE, *F.R.S.*

These photographs were of the same nature as those exhibited at the Meeting in 1859, to show that the alteration of the refrangibility of the extreme rays of the spectrum by fluorescent substances reduces their chemical activity. But as it had been objected that the lessened photographic effect might be due to a change of surface through wetting the paper and coating it with a salt, a crucial experiment was made by writing on a piece of white paper with black ink, bisulphate of quinine, bisulphate of potash, common salt, and pure water. When this was photographed, the writing in water or in the non-fluorescent salts was not perceptible, but the fluorescent quinine was strongly rendered, though not so strongly as the ink. In another photograph, however, two glasses filled respectively with ink and with a very strong but colourless solution of quinine, came out equally almost black.

On the Dresser-Rutherford Diffraction-grating. *By* J. NORMAN LOCKYER, *F.R.S.*

On the Relation of Geometrical Optics to other Branches of Mathematics and Physics. *By* Professor CLERK MAXWELL.

The author said that the elementary part of optics was often set before the student in a form which was at once repulsive to the mathematician, unmeaning to the physical inquirer, and useless to the practical optician. The mathematician looked for precision, and found approximation; the physicist expected unity in the science, and found a great gulf between geometrical and physical optics; and the optician found that if he had to design a microscope, he was expected to combine the analytical power of a Gauss with the computative skill of a Glaisher before he could make head or tail of the formulæ. The author maintained that elementary optics might be made attractive to the mathematician by showing that the correlation between the object and the image is not only an example, but the fundamental type of that principle of duality which was the leading idea of modern geometry. The object and image were homographic figures, such that every straight line or ray in the one was represented by a straight line or ray in the other. The relations between

pairs of figures of that kind formed an important part of the geometry of position, an excellent treatise on which had been brought out by M. Theodor Reye. To the physicist he would exhibit the unity of the science, by adopting Hamilton's characteristic function as explained in his papers on systems of rays, and using it in the most elementary form from the very beginning of the subject, leading at once to the undulatory theory of light. At the same time the practical optician would learn what were the cardinal points of an optical instrument, and would be able to determine them without taking the instrument to pieces. Helmholtz and Listing had pointed out the advantages of the method to the oculist; and Beck had recently placed some of the elementary points in a clear light. Casorati had also exemplified some of the advantages of the method of homographic figures in elementary optics; but though Gauss, the modern founder of that method, and several others, had made honourable mention of the name of Roger Cotes, and of that theorem with respect to which Newton said that "if Mr. Cotes had lived we should have known something," no one seemed to have suspected that it would form the meeting-point of all the three methods of treating the science of optics.

On a Natural Limit to the Sharpness of the Spectral Lines.
By Lord RAYLEIGH.

[Published *in extenso* in 'Nature' for Oct. 2, 1873.]

On the Influence of Temperature and Pressure on the Widening of the Lines in the Spectra of Gases. By ARTHUR SCHUSTER, *Ph.D.*

The question has often been discussed whether it is temperature or pressure which causes the widening of the lines in the spectrum of hydrogen. Some spectroscopists are of opinion that this widening of the lines is caused by the clashing together of the gaseous molecules, while others seem to think that the forces which maintain the molecule in vibration are altered by the temperature, and now allow the molecule to vibrate in different or less-defined periods. It is difficult to decide the question by experiment. The only means we have to render the gas luminous is to pass an electric current through it. But we know not in what way this current influences the velocity of the molecules, and therefore the number and force of the shocks. We cannot alter the temperature of the spark without altering the pressure within it; and therefore we cannot decide the question, as has been tried, by merely changing the mode of discharge. The following considerations seem to me to be strongly in favour of the view that each separate molecule would show at all temperatures the narrow lines, but that the shocks of the other molecules cause the widening. Frankland and Lockyer have found that if we increase the pressure of hydrogen while an electric current is passing through it, the lines begin to expand, all the spectrum becomes continuous, and, finally, the resistance becomes so large that the electric current will not pass at all. On the other hand, Gassiot and Plücker have observed that if we diminish the pressure of hydrogen its electric resistance diminishes, attains a minimum, then increases again; and if we keep on exhausting the tube, it becomes so great again that the current cannot pass. Plücker says that a tube exhausted to its utmost limits shows the lines of hydrogen and silica. He says at one place, "I think that the lines are very fine and distinct." If there had been any widening, he would have been sure to mention it. Now it is not too much to assume that the resistance of the gas at the moment when the discharge just ceases to pass is the same whether the increase of resistance is produced by too great a pressure or too great an exhaustion. At this moment, therefore, the current is the same, and the same energy must be converted into heat by resistance. But in the case in which the current does not pass on account of the excessive diminution of pressure, there is only a much smaller quantity of gas to be heated than in the other case; it must consequently be heated up to a much higher temperature; and yet the spectrum is not continuous; the lines are not even widened. We are therefore compelled to accept Frankland and Lockyer's original conclusion, that pressure, and not heat, is the cause of the widening of the lines.

On a curious Phenomenon observed on the top of Snowdon. By ARTHUR SCHUSTER, *Ph.D.*

This was a short account of a curious phenomenon observed by the author two years ago on the top of Snowdon. He saw his own shadow surrounded by five concentric coloured bows, which seemed to approach as the fog came nearer, until at last he saw the shadow of his head surrounded by a brilliantly coloured ring. Similar phenomena have often been observed; but so great a number of bows has never been seen.

HEAT.

On Thermal Conductivity. By Prof. G. FORBES.

Notes of some Experiments on the Thermal Conductivities of certain Rocks. By Prof. A. S. HERSCHEL, *B.A., F.R.A.S.*

The paper read was an abstract of the physical portion of that communicated to the Geological Section by Professor Herschel and Mr. G. A. Lebour. It was remarked that the principal difficulty in determining thermal conductivities from experiments with thin plates, is to ascertain the real temperatures of their faces during the transmission of the heat. The measurements of temperature were made with thermoelectric couples of thin platinum and iron wires connected with a Thomson's reflecting galvanometer; and it was found that although enclosed between two metallic plates differing as much as 80 or 90° C. from each other in temperature, the corresponding range of temperature between the two surfaces of the half-inch rock plates employed in the experiments only amounted at most to between 3° and 5° C., while the amount of heat transmitted with this range corresponded very nearly to the approximately known thermal conductivities of the rocks. The thermal resistance between the surfaces of solid conductors and air or other fluids in which they are immersed having been shown by Peclet to arise from an adhering film of the badly conducting fluid with which they are in contact, it is proposed in another series of experiments, by varying the thicknesses of the conducting plates, to ascertain the laws of this resistance, and, if they admit of a convenient interpretation, to arrive at some simple means of eliminating the effects of its influence upon the calculated results of experiments like those to which the various rock-specimens now examined have hitherto been provisionally submitted, and to obtain exact determinations of their real powers of conducting heat.

On the Correlation between Specific Weight and Specific Heat of Chemical Elements. By Prof. ZENGER.

ELECTRICITY AND MAGNETISM.

On the Molecular Changes that accompany the Magnetization of Iron, Nickel, and Cobalt. By W. F. BARRETT.

On the Relationship of the Magnetic Metals, Iron, Nickel, and Cobalt. By W. F. BARRETT*.

* See the Philosophical Magazine for December 1873, p. 478.

On Symmetric Conductors, and the construction of Lightning-conductors. By Prof. Ch. V. Zenger*.

It is an experiment very well known in physics, to place two insulated metallic hemispheres in contact with an insulated sphere of brass. If the former be charged with electricity and removed from the inner brass sphere, no trace of electricity is found on its surface. The electricity is shown to be accumulated only on the surface of the outer spherical conductor, with equal tension at every point of that surface.

The author shows that if the outer hemispheres be replaced by two circular wires, no action whatever will be found on the inner conductor. This fact may be best illustrated by the apparatus shown, which consisted of a very sensitive electroscope placed on a brass plate, supported by a well-insulated stand. If a charged ebonite rod be brought near to the electroscope when protected by two circular wires placed round it, in such a manner as to be in connexion with its gold leaves, or even if it is brought into contact with the ball of the electroscope, there is no action upon the leaves; and if the electrified rod be brought between the two wires and the electroscope itself, only a small action is observed. The author has tried this experiment with a powerful electric machine (a Holtz machine), and finally with a large induction-coil of Ruhmkorff; and the result was, that sparks of 35 centims. length produced no effect on the electroscope.

At the request of M. Faye, Ruhmkorff made similar experiments with his largest electric machines, putting a workman in the space between the protecting wires. There was no sensation of electric shocks on using the most powerful electric machine, though a shock was felt on the head of a workman when a large induction-coil was used. The author showed that the effect produced by the action of the pointed needle, though greatly diminished by the wires, is yet sensible, and that in Ruhmkorff's experiment a discharge produced by the interference of a pointed body may account for the difference observed by him.

It is easy to see that this experiment may prove useful in regard to the construction of electric apparatus and of lightning-conductors. The author, therefore, has examined the action of other forms of symmetrically-arranged conductors. In the first instance he tried parabolic wires, joined in the same manner to the electroscope to be protected from the action of electricity, with the same effect; next rectangular wires. If the electroscope is placed exactly in the middle of the rectangular wire, no action is observed; placing it excentrically, there is small but increasing action, at least if electric sparks of great intensity are striking the ball of the electroscope. If a needle or any other sharp-pointed body is placed between the protecting wire and the electroscope, it is easy to observe the different actions produced by placing the electroscope in an excentrical position.

Symmetrical wires placed on buildings or over entire cities in this way, would probably give complete protection from atmospheric electricity; for if the electric clouds were even to enter between the objects protected and the protecting wires, their activity would be greatly diminished, as shown by the experiments described; for the wires would become immediately charged, and nearly all the electricity would be accumulated on their surface, without any danger to the protected buildings of being struck by lightning.

Meteorology &c.

On the Undercurrents of the Bosphorus and Dardanelles. By William B. Carpenter, *M.D., LL.D., F.R.S.*

In continuation of his communication last year on the Gibraltar Undercurrent and General Oceanic Circulation, Dr. Carpenter gave the following summary of the results of the experiments recently made, under direction from the Admiralty, by Capt. Wharton of H.M.S. 'Shearwater,' to put to the test the correctness of Dr.

* *Vide* Comptes Rendus de l'Académie des Sciences, Sept. 8, 1872; Le Monde, Sept. 1872.

Carpenter's theoretical conclusion that a strong undercurrent must exist between the Ægean and the Black Sea.

Although it is commonly supposed that the Dardanelles and the Bosphorus *surface*-currents are *overflow*-currents, carrying off the excess of fresh water discharged by rivers into the Black Sea, yet it is now clear that they are in great measure *wind*-currents. During about three quarters of the year the wind blows pretty steadily from the N.E. (that is, down the Straits); and, as a rule, the stronger and more continuous the wind, the stronger is the surface out-current. On calm days, the out-current of the Dardanelles is usually slack; and if, as sometimes happens, a strong wind blows from the S.W., its flow may be entirely checked. It requires a continuance of strong S.W. wind, however, to reverse its direction; and its rate, when reversed, is never equal to that of the out-current. The speed of the Dardanelles current varies at different parts of the Strait, according to its breadth—being usually about one knot per hour at Gallipoli, and three knots in the "Narrows" at Chanak Kaleksi, where, with a strong N.E. wind, it is sometimes as much as four and a half knots, the average of the whole being estimated by Capt. Wharton at one and a half knots.—The Bosphorus current has not been as carefully studied as that of the Dardanelles; but Capt. Wharton states that its rate is greater, averaging about two and a half knots per hour, apparently in consequence of the limitation of its channel, which is scarcely wider at any point than is the Dardanelles at the "Narrows." It continues to run, though at a reduced rate, when there is no wind; and it is only in winter, after a continued S.W. gale of long duration, that a reversal of the Bosphorus current ever takes place.

It might have been supposed that, as the greatest depth of these two Straits does not exceed fifty fathoms, the determination of the question as to the existence of an undercurrent would be a comparatively easy matter. But it is rendered difficult by the very rapidity of the movement, alike in the upper and the lower stratum; and the results of the earlier experiments made by Capt. Wharton, in which he used the current-drags that had been found to work satisfactorily in the Strait of Gibraltar, were not conclusive. But perceiving from the very oblique direction of the suspending line, that the undercurrent must be acting on the current-drag at a great disadvantage, Capt. Wharton set himself to devise a drag which should hang vertically, even when the suspending line was oblique, so as to expose a large surface to the impact of a current at right angles to it This worked satisfactorily, and gave the most conclusive evidence of the existence of a powerful undercurrent, by dragging the suspending buoy *inwards* against the surface-current; the force of which, aided by wind, was sufficient on several occasions to prevent the row-boats from following the buoy, only the steam cutter being able to keep up with it. The following, which is the most striking of all his results, was obtained in the Bosphorus on the 21st of last August, with a surface-current running outwards at the rate of three and a half knots per hour, and a N.E. wind of force 4. "When the current-drag was lowered to a depth afterwards assumed to be twenty fathoms, it at once rushed violently away against the surface-stream, the large buoy and a small one being pulled completely under water, the third alone remaining visible. It was a wonderful sight to see this series of floats tearing through the water to windward. The steam cutter had to go full speed to keep pace with it." It is obvious that the real rate of the undercurrent must be very much greater than that indicated by the actual movement of the float, since the current-drag impelled by it had to draw the large suspending buoys and the upper part of the line against the powerful surface-current running at three and a half knots an hour in the opposite direction, *their* motion through the water therefore being nearly four and a half knots an hour.

The difference in the specific gravity of water obtained from different depths was usually found in Capt. Wharton's investigations (as in the author's) to afford, under ordinary circumstances, a very sure indication of the direction of the movement of each stratum; the *heavy* water of the Ægean flowing *in*wards, and the *light* water of the Black Sea *out*wards. And it was indicated alike by both modes of inquiry, that the two strata move in opposite directions, one over the other, with very little intermixture or retardation, the passage from the one to the other being usually very abrupt. In a few instances there was a departure from the

usual rule—an *out*ward movement being found in the *deepest* stratum, while the middle stratum was moving *in*wards, though the water of both these strata had the density of the Ægean. These anomalies are considered by Capt. Wharton to proceed from the prevalence of opposite winds at the two ends of the Strait.

As a general rule, the strength of the *in*ward undercurrent was proportioned to that of the *out*ward surface-current; and this was very remarkably shown in cases in which, both having been slack during a calm, an increase of wind augmented the rates of both currents alike. That a wind blowing *out*wards should promote the flow of an undercurrent *in*wards, may at first sight appear anomalous; but it is very easily accounted for. Suppose that a moderate S.W. wind, by checking the surface-outflow, keeps the level of the Black Sea just so much above that of the Ægean that the greater *weight* of the latter column is counterpoised by the greater *height* of the former; then, as the *bottom* pressures of the two are equal, their *lateral* pressures will also be equal, and there will be no undercurrent so long as this condition lasts. But so soon as, on the cessation of the S.W. wind, the level of the Black Sea is lowered by a surface-outflow, the Ægean column comes to be the heavier, and its excess of lateral pressure produces a deep inflow. And when this *out*flow is further aided by a N.E. wind, so that the levels of the two seas are equalized, or there is even an excess of elevation at the Ægean end, the greater weight of the Ægean column will produce a greater lateral pressure, and will consequently increase the force of the *in*ward undercurrent.

The result of this *experimentum crucis* may be fairly considered to have clearly shown that a slight excess of *downward pressure*—whether arising from difference of *specific gravity*, or from difference of *level*—is quite adequate to produce movement in great bodies of water, which movement may have the rate and force of a *current* when restricted to a narrow channel. And the "creeping-flow" of Polar water along the Ocean-bottom, which, on Dr. Carpenter's theory of Oceanic circulation, brings a glacial temperature into the Intertropical zone, is thus found to have an adequate *vera causa* in the excess of deep lateral pressure exerted by the Polar column, whose density has been augmented by cold, over that of the Equatorial column, whose density has been diminished by heat,—the levels of the two columns being assumed to be the same.

On the Refraction of Liquid Waves. *By* W. S. Davis.

Lunar Influence on Clouds and Rain. *By* J. Park Harrison, *M.A.*

On tabulating the mean quantities of cloud at Greenwich in 1871 according to the age of the moon, the results agreed generally with the mean rainfall on certain days of the lunation as ascertained by Mr. Chase, an American savant, and Mr. Hennessy, at Mussoorie, in India. The author pointed out the necessity of obtaining special observations, not only of the amount of cloud, but also its height above the earth, before any certain conclusions as to the full extent of lunar influence on the atmosphere, and consequently on air-temperature, can be arrived at. He had shown in former communications that temperature is sensibly affected by the moon.

On the Application of Telegraphy to Navigation and Meteorology. *By* Asturo de Marcoartu.

On a Periodicity of Cyclones and Rainfall in connexion with the Sun-spot Periodicity. *By* C. Meldrum.

[Ordered to be printed *in extenso* among the Reports.]

On Experiments on Evaporation and Temperature made at Wisbeach. By S. B. J. Skertchly.

On the Passage of Squalls across the British Isles. By G. M. Whipple, B.Sc., F.R.A.S., of the Kew Observatory.

After exhibiting the uncertainty attendant upon investigation of meteorological laws by the aid of observations made over a small part of the earth's surface like the British Isles, owing to the want of well-marked characteristics which would serve to identify and track out masses of air moving over the country, the author calls attention to squalls which, occurring abruptly and presenting certain definite features, are recorded in a conspicuous manner by self-registering meteorological instruments when they pass over them.

The appearance of the instrumental curves at the time of a squall was described and illustrated by means of tracings from the Quarterly Weather Reports of the Meteorological Committee; and a table was given showing a brief history of twenty-three squalls, registered in the Reports from 1869–73.

From this it appeared that their motion is almost invariably in a direction from westward to eastward, with a velocity diminishing as they progress.

The velocity of the easterly motion is sometimes as high as 100 miles per hour, and falls as low as 10 miles, the average rate given by the whole series being 38 miles per hour.

Referring to other papers which have appeared on these phenomena, the author suggests that use might with advantage be made of a better knowledge of squalls in issuing storm warnings.

Instruments.

On Dynamometers in Absolute Measure. By Robert Stawell Ball, LL.D., F.R.S.

On an Improvement in the Sextant. By Capt. J. E. Davis, R.N., F.R.G.S.

This small adaptation to the sextant is intended principally to facilitate the taking observations of heavenly bodies, of course with the view of fixing positions, rating chronometers, &c. It consists of two parts, viz. the micrometer and the indicator. The micrometer is simply a toothed wheel attached to the tangent-screw; and to the arm of the sextant is attached a pawl or click, adapted to the toothed wheel. Each tooth represents one tenth of the circumference or turn of the tangent-screw; so that (presuming the tangent-screw to be correct) whatever alteration one turn of the screw makes in the reading on the arc, each click represents exactly one tenth of that movement; thus, if one turn of the screw moves the vernier 20 minutes, each click moves it exactly 2.

The indicators are two movable brass slides, one placed before the arm, the other behind the arm of the sextant, and capable of being clamped firmly. By means of these there is no necessity to read off the observations at the time of observing.

The micrometer movement can be disconnected at pleasure by means of a small eccentric, which lifts the pawl.

In using the sextant, if the heavenly body is rising, the indicator behind the arm is moved with the arm in bringing the reflected image down; and before it comes into contact either with the horizon or its own reflection in the artificial horizon, the arm is clamped, and the indicator also. The first contact is the first observation. The tangent-screw is then quickly turned one or two clicks; this opens or separates the two images, which, on coming into contact again, form the second observation; and so on.

The advantages claimed for this little invention are :—

1. Simplicity in the mode of observing.—The author maintains that observations can be more perfectly made with a sextant by allowing the objects to come into contact, and noting the moment of contact, than by bringing them into contact and noting that time; thus the observations of the traveller inexperienced in the use of the instrument will prove of more value by this mode of observing than by that usually followed.

2. In star observations.—Every observer knows full well the difficulty attending taking star observations, the trouble in keeping the lamp trimmed, then that of bringing the focus of the light on to the vernier in reading off, and the delay consequent. There is also a physical difficulty; viz., in observing, the pupil of the eye has to be dilated to take in the greatest possible quantity of light, and suddenly contracted to exclude it in reading off, to be as suddenly changed again. These difficulties, the author believes, are avoided by this simple adaptation. If circummeridian altitudes are being observed, all the altitudes before and after crossing the meridian are equal; and if it be necessary to record the meridian altitude itself (which may occur between the clicks), it can be done by the indicator before the arm; but the meridian altitude is not absolutely necessary.

3. Two sets of star observations can be made by the same sextant without reading off, provided their altitudes are not the same.—Having taken the first set (say the one with the lowest altitude), the indicator behind the arm is left to record it, and the indicator before the arm will record the other.

4. In equal altitudes of the sun, before and after noon, for time.—After taking those in the forenoon, the sextant may be left until the last observation taken comes on in P.M., and the altitudes respectively worked back to the first of the forenoon.

5. In lunar observations.—Every observer of lunar distances on board ship knows the difficulty attending taking these observations. When there is much movement in the vessel it takes some time to get the sextant on; but when once it is got on the proper angle, he can *keep* the objects in contact. By means of the micrometer he is not necessitated to remove the sextant from the eye, and can go on taking his distances *ad libitum*.

6. In thick or cloudy, or even rainy weather, when a heavenly body can only be seen for a short time, the observer is not dependent on one observation, but can take a set in less time than he could one or two by the ordinary process.

7. The check on the time-taker.—A good observer has a difficulty in checking his time-taker. The process to detect error is rather long and complicated; but the measurements of arc being equal by the micrometer, an error in time is at once detected.

8. In nautical surveying.—The indicator attached to the ordinary sounding quintant will prove useful by enabling the two angles, to fix a position, being taken without removing the sextant from the eye, and thus avoiding the necessity of having two observers (often necessary), or the use of a double sextant.

On an Instrument for the Composition of two Harmonic Curves. *By* A. E. Donkin, *M.A., Fellow of Exeter College, Oxford.*

Since a simple harmonic curve may be regarded as the curve of pressure on the tympanic membrane when the ear is under the influence of a simple tone, a curve compounded in the ordinary way of two such harmonic curves will be the curve of pressure for the consonance of the two tones which they severally represent.

Hence a machine which has for its object the composition of two harmonic curves, possesses the means for rendering distinctly visible to the eye the effect on the ear of the consonance of any two simple tones.

If a pencil-point performs rectilinear harmonic vibrations upon a sheet of paper moving uniformly at right angles to the direction of these vibrations, it describes a simple harmonic curve. If there be now given to the paper, in addition to its continuous transverse motion, a vibratory motion similar and parallel to that which the pencil has, a complicated curve will be the result, whose form will depend on

the ratio of the numbers of vibrations in a given time of the pencil and paper, and which will be the curve of pressure for the interval corresponding to this ratio. The way in which the machine combines these three motions is as follows. There are two vertical spindles capable of revolving in a horizontal plate. At the lower end of each a crank is fixed; and at the upper end of each a toothed wheel can be screwed on: this pair of wheels can be connected by a third intermediate one.

The paper upon which the curve is to be drawn is carried upon a rectangular frame, capable of sliding horizontally up and down. The frame has a pair of horizontal rollers at each end, between which the paper passes as the rollers turn; and a uniform motion is given to them by means of a long pinion working into the teeth of a wheel fixed on one of them, and up and down which the frame slides. This long pinion is turned by one of the vertical spindles. A connecting-rod is carried from the crank of this spindle to the frame, by means of which a vibratory motion is communicated to the latter, which motion, though not truly harmonic, is, owing to the length of the connecting-rod and small radius of the crank, quite sufficiently so for practical purposes. A similar and parallel motion is given to a small glass pen by means of a connecting-rod from the other crank. This pen is so arranged as to rest upright with its point upon the paper. If the intermediate wheel be now put into gear with those on the spindles, and either of them turned by a winch provided for the purpose, a curve corresponding to the ratio of the numbers of teeth on the spindle-wheels will immediately be drawn.

The general form of equation to the curves which the instrument can produce will evidently be

$$y=a\sin(mx+\alpha)+b\sin(nx+\beta).$$

Here a and b are the radii of the cranks, which can be altered at pleasure from 0 to half an inch; m and n are limited by the numbers of teeth of the wheels with which the instrument is provided, while α and β depend on the phases of the cranks, *i. e.* the relative position they are in with respect to the vertical plane passing through their axes when the intermediate wheel is brought into gear with them.

As an example, by taking $m=54$, $n=27$, $a=b=$ half an inch, the curve drawn will be that corresponding to an octave. Substituting a wheel of 55 teeth for that of 54, the curve alters its form to that representing an octave out of tune. Again, the numbers 48 and 45, which have the ratio $\frac{16}{15}$, would give the curve corresponding to a diatonic semitone. The form of this curve, as of all others where the ratio approaches unity, shows very distinctly the beats which would ensue upon sounding the corresponding consonance.

Since it is possible to vary the radii of the cranks at pleasure, the curves corresponding to the consonance of two tones of unequal intensity can also be drawn. The length of paper within which the period of any curve is contained depends on the rate at which the rollers turn. Since this can be regulated at pleasure, by means contrived for the purpose, the curves may be either extended or compressed; that is, the period may be made either long or short. The general form of any curve, however, is better seen in the latter case. The maximum width of contour in any curve is equal to twice the sum of the radii of the cranks. Thus when these are each half an inch, the curve will be two inches wide.

The instrument is constructed by Messrs. Tisley and Spiller, of Brompton Road, to whom several improvements on the original model are due.

On an Improved Form of Aneroid for determining Heights, with a means of adjusting the Altitude-scale for various Temperatures. By ROGERS FIELD, *B.A.*

The author begins by stating that the object aimed at in designing this improved form of aneroid was to simplify the correct determination of altitudes in cases such as ordinarily occur in England, and that the instrument is therefore arranged to suit moderate elevations, say of 2000 feet and under, and is not intended for considerable elevations.

The table which is adopted in graduating the aneroid described is that given

by the Astronomer Royal in the 'Proceedings of the Meteorological Society,' vol. iii. page 406, and gives results which lie between those of other authorities.

Aneroids constructed for the determination of elevations by readings from an altitude-scale consist of two classes—one in which the altitude-scale is fixed and the other in which it is movable. The first class of aneroid, with a fixed scale, is accurate in principle; but the scale only allows for one of the conditions which have to be taken into account, viz. the varying *pressure* of the atmosphere; and the other condition or *temperature* of the atmosphere has to be allowed for by calculation. The second class of aneroid, that with a movable scale, is radically wrong in principle as ordinarily used, inasmuch as the movable scale must be graduated for one fixed position of the zero; and when the zero is shifted at random, according to the position of the hand of the instrument, the scale necessarily becomes inaccurate.

In the improved aneroid the scale of altitudes is movable, but, instead of being shifted at random according to the position of the hand of the instrument, it is moved into certain fixed positions according to the temperature of the atmosphere; so that the shifting of the scale answers the same purpose as if the *original* scale were altered to suit the various temperatures of the atmosphere. The aneroid is graduated for inches in the usual way on the face; but the graduation only extends from 31 to 27 inches, so as to preserve an open scale. The outer movable scale is graduated in feet for altitudes; and the graduation is laid down by fixing the zero opposite 31 inches. This is the normal position of the scale; and it is then correct for a temperature of 50° Fahr. For temperatures below 50° the zero of the scale is moved below 31 inches; and for temperatures above 50° the zero of the scale is moved above 31 inches: the exact position of the zero for different temperatures has been determined partly by calculation, and partly by trial, and marked on the rim of the aneroid. In order to ensure the altitude-scale not being shifted after it has once been set in its proper position, there is a special contrivance for locking it in the various positions. The altitudes are in all cases determined by taking two readings, one at each station, and then subtracting the reading at the lower station from that at the upper.

The movable scale requires to be set for temperatures before taking any observation, and not shifted during the progress of the observations. This will practically not give any inconvenience in the case of moderate altitudes, as small variations of temperature will not appreciably affect the result; and so long as the temperature does not vary during the course of the observations more than 5° from that at which the instrument is set, the result may be accepted as practically correct.

In conclusion the author states that the principle of allowing for the variations of temperature of the atmosphere by shifting the altitude-scale, does not profess to be theoretically accurate, but simply sufficiently accurate for practical purposes. In order to satisfy himself that this was the case, the author carefully compared the readings obtained for different temperatures from the shifted scale with the correct readings as given by calculation from the normal position of the scale, and found that the maximum error was 2 feet and the average error under 1 foot, errors which are perfectly inappreciable. The instrument was constructed by Mr. Casella, of Holborn Bars, London.

On Eckhold's *Omnimeter, a new Surveying-Instrument. By* G. W. Hope.

On Negretti *and* Zambra's *Test-gauge Solar-Radiation Thermometer. By* G. J. Symons.

Meteorologists have long been endeavouring to obtain an instrument whereby comparable observations of the amount of solar radiation could be made. Various experiments and observations by the Rev. F. W. Stow, the late F. Nunes, Esq., M.A., and the author have shown that this object is attained by the use of a mercurial maximum thermometer, of which the bulb and one inch of the stem are

coated with dull black, which thermometer is enclosed in a glass jacket, the bulb being in the centre of a sphere of not less than two inches diameter, and from which jacket nearly all the air has been exhausted. To all thermometers thus mounted the title of vacuum thermometer has been applied. It has, however, been found that the amount of exhaustion varies considerably, and that the indications of the thermometer are thereby greatly affected. Yet the instruments hitherto made have been indiscriminately sold and used, and no ready means have been available for determining the amount of air left in.

The speciality of the instrument now exhibited is, that a small vacuum-gauge is inserted in the jacket, so that the precise extent to which the exhaustion has been carried can be seen at any time, and strict comparability in this important respect ensured.

On a Compound-Pendulum Apparatus. By S. C. Tisley.

This apparatus was originally designed for the purpose of recording the figures shown in Lissajous's experiments with tuning-forks.

The method of obtaining the vibrations is by means of two pendulums, which work upon knife-edges, the supports being secured to two sides of a piece of mahogany, so that the pendulums swing at right angles to each other. The pendulums are about 3 feet long, and are continued above their supports about 8 inches, finishing at their tops in ball-and-socket joints. Wire arms are screwed into the ball-and-sockets, and connected with a pen or tracer. When at rest, the two pendulums and tracer are at three corners of a square. One pendulum has two sliding pans for holding weights, one above the point of suspension and one below; the other pendulum has two sliding pans, but both below the point of suspension; four weights are generally used, each weighing about $2\frac{1}{2}$ lbs.

When a single weight is placed on each of the bottom pans and properly adjusted, the vibrations of the two pendulums being equal, the figure formed by the tracer will be an elliptical spiral, gradually dying out so as to produce a watch-spring-shaped curve. A small sliding weight is attached to the first pendulum; and by moving this up or down, the vibrations can be brought perfectly into unison, or thrown slightly out of time, thus producing through the tracer a variety of complicated and interesting figures. The second pan is used for varying the rates of vibration of the two pendulums in certain ratios, so as to produce curves of different characters. A variety of tracings illustrating this were exhibited.

The use of the pan above the point of suspension is of great value, as it gives a ready means of altering the proportions. Thus by moving the weight ($2\frac{1}{2}$ lbs.) from a pan below to one above the point of suspension, and placing a balance-weight of $\frac{1}{2}$ lb. on the lower pan, the pendulums having originally been adjusted for unison, the resulting vibrations will be in the ratios of 3 to 1; and if they had been adjusted to 3 to 2, the result would be 2 to 1, and so on.

In the table under the tracer a glass plate is let in, so that, by placing a reflector below and above, a light can be thrown through the object, and a magnified image produced on the screen during its formation; in that case blackened glass and a needle-point for tracer are used.

On a new form of Pendulum for exhibiting Superposed Vibrations. By Professor A. S. Herschel, *B.A., F.R.A.S.*

The contrivance exhibited originally presented itself to the author at the Observatory of R. S. Newall, Esq., Gateshead-upon-Tyne, where the observing-chair is supported by a counterpoise consisting of a horizontal iron bar loaded with weights, and fastened at its two ends to wire ropes, which, passing over two pulleys, support the chair. When the chair-frame was moved, the two ends of this pendulum showed themselves to be capable of three modes of vibration—one longitudinal (in the direction of the bar's length), and two transversal ones proceeding from the bar's displacement either angularly about its middle point or parallel to itself. The combination of the first two of these movements together made the end of the

swinging bar describe compound vibration-curves of the form known as Lissajous's, of great regularity and distinctness, and was suggested to the author by Mr. Newall as a new means of tracing them. In the new instrument the horizontal bar is hung by four strings forming a W; and the outer pairs are nipped together at equal distances from the rod at whatever height above it gives the desired period of its longitudinal vibrations. Its transversal vibrations are of two kinds, either of bifilar torsion, or of simple lateral oscillation about the three upper points of suspension. The points of attachment on the bar are a little above its axis, which passes through the centre of gravity of a large fixed weight at its middle point; two smaller sliding weights, moved along it, regulate the rate of its angular oscillations. The new pendulum possesses a fourth mode of vibration—of rotation round the line of attachment in the bar, like the rolling of a ship at sea—a condition of oscillation very similar to one which was lately ingeniously employed to illustrate that problem by Sir William Thomson. If the bar "rights" quickly round this axis, these small rolling oscillations do not accumulate very greatly, and soon disappear; but if they are nearly of the same period as the principal transverse vibration, they are so large and persistent as entirely to disturb the regularity of the curves. A glass pen fixed to the end of the bar traces Lissajous's curves by combining the longitudinal with either of the two transversal vibrations. When both of the latter act together, wavy modifications of Lissajous's curves are produced, which present cusps, stationary points, and other interesting varieties of form [of which some illustrations were exhibited]. Their general expression is given by the equations

$$\begin{cases} x = \mathrm{A}\cos(a+at) \\ y = \mathrm{B}\sin(b+\beta t) + \mathrm{C}\sin(c+\gamma t), \end{cases}$$

which only differ from those of Lissajous's curves by the addition of a second independent term at the end of the last equation.

On the Influence of Temperature on the Elastic Force of certain forms of Springs. *By* F. H. Wenham.

The author stated that the value of springs in the form of elastic plates or rods subject to deflection or torsion, in the construction of instruments for measuring and regulating force, temperature, and time, depends upon the law that the degrees of motion are equal to the forces, and that this equality of force and motion is identified with the *time* in which those motions are performed; for the vibration of certain forms of springs is performed in the same time, whether the degree of motion is great or small: such a spring will give the same musical note at all ranges, and have the important property of isochronism, as illustrated in the balance-springs of chronometers, meaning that the time is the same at all ranges in the arc of vibration. The author pointed out that the form of balance-spring commonly used in time-pieces is not strictly isochronal; for beyond one revolution the forces are unequal, increasing during winding and decreasing in the opposite extreme of uncoiling, but that in the acting range of vibration of these instruments the differences were not appreciable.

Instruments for measuring force, temperature, or time, such as aneroid barometers, thermometers, or chronometers, the accuracy of whose indications depends upon the uniform elasticity of springs, require a compensation to counteract the loss of elasticity by increase of temperature. A number of experiments were tried and detailed by the author, in order to determine a law to enable the compensations to be effected definitely. The materials experimented upon were steel, hardened and tempered, crown-glass, brass, and german silver highly condensed by hammering. These materials, while under various degrees of compression, were subjected to temperatures ranging up to 500°; but it was found that the loss of elasticity did not correspond in a regular ratio with the increase of heat; for example, in a steel spring each hundred degrees from 100° to 500° caused deflections in the ratio of 13, 16, 40, and 52; and, in first experiments, when the springs had cooled they did not return to their normal point with the pressure remaining the same, but had acquired

a permanent set, which was great at first (in an untried material), but became less by repetitions of the experiments.

With hard hammered german silver the set *at first* much exceeded that of steel, being equal to one-third of the compression, but after four repetitions of the experiment amounted to only one twenty-seventh. This metal, unlike steel, indicated equal deflections with equal degrees of heat, showing that, in instruments where it could be used, no *secondary* compensation would be required, because the ratio is equal for mean and extreme temperatures.

These experiments demonstrate, in regard to any instrument for indicating and registering weight, pressure, temperature, or time by means of the law of elasticity, the importance of subjecting the material (whether steel, glass, or particularly any metal in which this property is obtained by condensation or hammering) to an excess of temperature before the graduations and adjustments are made.

On a New Form of Rutherford's *Minimum Thermometer, devised and constructed by* Mr. James Hicks. *By* G. M. Whipple, *B.Sc., F.R.A.S., of the Kew Observatory.*

Many different kinds of thermometers have been constructed for the purpose of indicating the lowest temperature of the air during a given time; but none has been found to fulfil the desired object so well as the common or Rutherford spirit-thermometer.

The chief objection to the use of this instrument is found to be in the fact that the spirit-thermometer cannot follow sudden variations of temperature so quickly as the mercurial thermometer; hence, on occasions when rapid changes occur, the indications of the two instruments are not accordant.

In the thermometer exhibited Mr. Hicks has in a great measure succeeded in overcoming this difficulty by the device of largely increasing the surface of the bulb exposed to the air, whilst at the same time he greatly reduces its cubical contents.

In 1862 Mr. Beckley suggested the formation of thermometer-bulbs on the pattern of certain bottles, in which the bottom is forced up a long way into the body, and Mr. Hicks constructed a mercurial thermometer, which was shown in the International Exhibition. Practical difficulties, however, obstructing the manufacture of this kind of thermometer, very few have been made. Recently Mr. Hicks endeavoured to make spirit-thermometers upon the same principle, and having succeeded can now construct bulbs in the form of a hollowed-out cylinder, with the film of spirit reduced to any degree of tenuity.

In order to determine the relative advantages of the old- and new-pattern thermometers, experiments have been made at the Kew Observatory, which show that the time Hicks's minimum thermometer requires to fall through 25° Fahr. is 55 seconds, whilst a common spherical-bulb minimum takes 2 minutes 25 seconds to fall through the same extent of scale; and Hicks's rises 25° in 57 seconds, the other thermometer occupying 2 minutes 24 seconds to rise through the same interval.

An improved form of the instrument has the bulb in the form of a double tube open at both ends, allowing free passage of the air through it.

On a New Electrical Anemograph. *By* G. M. Whipple, *B.Sc., F.R.A.S., of the Kew Observatory.*

Amongst the numerous instruments which have been devised for recording continuously and automatically the velocity and direction of the wind, none has met with more general adoption than the form known as the Beckley or Kew-pattern Anemograph.

This instrument was originally constructed in 1857, by a grant from the British Association; and a detailed description of it, with Plates, is to be found in the Report of the Association for the year 1858.

Some minor modifications found necessary having been introduced into the instrument, it was accepted by the Meteorological Committee; and it is now employed

by them in their observatories, its essential features being identical with the 1858 instrument.

Experience has shown that under most circumstances the working of this instrument leaves but little to be desired, but that in situations where it is necessary to place the recording-apparatus at a considerable distance from the external driving parts of the instrument its action is subject to irregularities, due principally to the yielding of the long, light shafts which have then to be employed; and it is to meet such cases that the modification now brought before the Association has been devised by me.

No originality is to be found in the adaptation of electricity to the purpose of registering the wind; numerous arrangements have been made by which it can be accomplished. I need only allude to Secchi, Crossley, Gordon, Hall, and others who have constructed instruments which do it.

In my plan for the velocity-recording apparatus, where rotation in one direction only is required, I employ, first, a simple contact-making key, on the shaft carrying the Robinson's cups, which transmits a short current every time the cups complete a revolution. This current is then led by means of a wire to the recording-apparatus placed at any distance; and there, by means of an arrangement of electromagnets and escapement similar to that employed in the step-by-step telegraph instrument, successive currents produce the continuous rotation of a wheel.

This wheel being put into connexion with the train of wheelwork at present existing, eventually drives the pencil round and records the wind's movement upon the paper.

The Direction-apparatus.—Registration of the wind's direction by means of electricity is somewhat difficult of execution by reason of the fact that rotation of the wind-vane occurs sometimes in a positive or right-handed direction, veering from and through E. and S., and sometimes *vice versâ*, or from N. through W. to S.

Various plans have been devised for accomplishing the thing desired, requiring wires varying in number from four to thirty-two. In the instrument now described two only are needed, one of which is employed to transmit the rotary motion of the vane to the recording-pencil, the other determining the direction in which the rotation is to take place.

A toothed wheel in electrical communication with a battery is fixed upon the vane-spindle, and a contact-breaker so arranged that a current is sent to the recording-apparatus every time a tooth passes.

Every current transmitted causes a wheel in the registering-apparatus to rotate through a small arc, always of course in the same direction.

In order to record *backing* of the wind, the second wire must be made use of. Above the contact-making wheel on the vane-spindle, and turning loosely in it, a small insulated metallic collar is fitted, immediately over which there is a metal disk fastened to and turning with the shaft; a stud projecting from the underside of this disk plays between two stops on the collar, one of which is a conductor, the other being an insulator.

The play of the stud between the two stops is merely sufficient to make and break the electrical contact.

The wire from the metallic stop is led to an electromagnet fixed above the recording-apparatus. A lever-clutch, moved by the armature of the magnet, acts upon the driving-spindle of the pencil cylinder, raising it when a current passes, and so bringing the lower of two mitre wheels fixed upon the spindle into gear with the mitre wheel turning the cylinder, on its under side, and causing it to rotate when the spindle is turned. When the current is discontinued, a spring draws the spindle downwards, and the top mitre wheel is brought into gear with the upper side of the pencil-wheel, whilst the lower one is set free; continued rotation of the spindle has now the effect of turning the pencil in the reverse direction to that in which it was previously moving.

Under ordinary circumstances this will be the position maintained; the vane-stud being in contact with the insulating stop, no current passes; should, however, the wind veer against the sun, the movement of the vane will make electrical contact, the sliding shaft be lifted, and, the lower wheel coming into gear, the rotation of

the shaft under the action of the second wire and contact-breaker will be transmitted to the pencil, and cause it to turn in the direction W. through S. to E. instead of the reverse.

It is necessary to make the fittings so exact that no movement of the shaft can occur without a corresponding motion of the pencil; otherwise the orientation of the instrument would be rendered incorrect.

The instrument above described has not yet been constructed: hence no information can be given as to battery power necessary to work it. Probably very little would suffice; for as the rotation of both shafts is continuous and in the same sense, the whole actual work of moving the pencils over the paper could easily be performed by a small weight or spring suitably arranged.

On an improved form of Oxyhydrogen Lantern for the use of Lecturers. By C. J. WOODWARD, *B.Sc.*

The author stated that the form of oxyhydrogen lantern generally used by lecturers was merely the old magic lantern, and this was not sufficient for the many requirements of the lecturer of the present day. What was required was a light lantern which would direct a beam in any direction whatever, and which would not only serve to show photographs and slides, but would do also for exhibiting experiments such as electrolysis of liquids, magnetic curves, cohesion-figures, &c.

The instrument the author exhibited consists of a small lantern swinging between two uprights. It can be clamped at any angle: and as the stand is one capable of rotating, the lantern can be made to project a beam of light in any direction. The stool of the lantern is constructed on the principle of Willis's apparatus for lecturers on mechanics: and to this is fastened carriers for a table to support a prism or other piece of apparatus. A projecting bar serves to hold the lenses, which slide on the bar and can be turned out of the way in a moment. The lantern was made for the author by Messrs. R. Field & Co., of Birmingham.

A description of the Instrument, with woodcuts, will be found in the 'Engineer,' vol. xxxvi. p. 284.

CHEMISTRY.

Address by W. J. RUSSELL, *Ph.D., F.R.S., President of the Section.*

OF late years it has been the custom of my predecessors in this chair to open the business of the Section with an address, and the subject of this address has almost invariably been a review of the progress of Chemistry during the past year; I purpose, with your leave, to-day to deviate somewhat from this precedent, and to limit my remarks, as far as the progress of Chemistry is concerned, to the history of one chemical substance. The interest and the use of an annual survey at these meetings of the progress of Chemistry has to a certain extent passed away; for the admirable abstracts of all important chemical papers now published by the Chemical Society has in a great measure taken its place, and offers to the chemical student a much more thorough means of learning what progress his science is making than could possibly be done by the study of a presidential address. Doubtless these abstracts of chemical papers are known to others than professional chemists; but I cannot pass them over without recording the great use they have proved to be, how much they have done already in extending in this country an exact knowledge of the progress of science on the Continent, and in helping and in stimulating those who are engaged in scientific pursuits in this country. I believe few grants made by this Association have done more real good than those which have enabled the Chemical Society to publish these abstracts.

I dwell for a moment on the doings of the Chemical Society; for I believe in the progress of this Society we have a most important indication of the progress of

chemical science in this country. The number of original papers communicated to the Society during the last year has far exceeded that of previous years; during last year fifty-eight papers were read to the Society, whereas the average number for the last three years is only twenty-nine. Further, I may say there is every appearance of this increased activity not only continuing but even increasing. Another matter connected with the Society deserves a passing word: I mean its removal from its old rooms at Burlington House, which afforded it very insufficient accommodation, to its new ones in the same building. This transference, which is now taking place, will give to the Society a great increase of accommodation, and thus admit of larger audiences attending the lectures, of the proper development of the library, and of the full illustration, by experiment, of the communications made to it. These improvements must act most beneficially on the Society, and stimulate its future development. Even now it numbers some 700 members, and certainly is not one of the least active or least useful of the many scientific societies in London.

Since our last Meeting at Brighton we have lost the most renowned of modern chemists, Liebig. His influence on chemistry through a long and most active life has yet to be written. Publishing his first paper fifty years ago, it is difficult for chemists of the present day to realize the changes in chemical thought, in chemical knowledge, and in chemical experiment which he lived through, and was, more than any other chemist, active in promoting. His activity was unwearied; he communicated no less than 317 papers to different scientific journals; and almost every branch of chemistry received some impetus from his hand.

Liebig took an active interest in this Association; and I believe the last paper he wrote was one in answer to a communication made at the last Meeting of this Association. On two occasions he attended Meetings of the British Association, and has communicated many papers to this Section. The Meeting at Liverpool in 1837 was the first at which he was present; he then communicated to this Section a paper on the products of the decomposition of Uric Acid, and, further, gave an account of his most important discovery, made in conjunction with Wöhler, of the artificial formation of Urea. At this Meeting Liebig was requested to prepare a report on the state of our knowledge of isomeric bodies. This request, although often repeated, was never complied with. He was also requested to report on the state of Organic Chemistry and Organic Analysis; thus our Section was evidently desirous of giving him full occupation. At the Meeting in 1840, at Glasgow, a paper on Poisons, Contagions, and Miasms, by Liebig, was read; it was, in fact, an abstract of the last chapter in his book on Chemistry in its applications to Agriculture and Physiology; and the work itself appeared about the same time, dedicated to this Association. In his dedication Liebig says:—"At one of the meetings of the Chemical Section of the British Association for the Advancement of Science, the honourable task of preparing a Report upon the State of Organic Chemistry was imposed upon me. In this present work I present the Association with a part of this Report."

At the next Meeting, which was at Plymouth in 1841, there was an interesting letter from Liebig to Dr. Playfair, read to our Section; in it, among other matters, Liebig describes an "excellent method," devised by Drs. Will and Varrentrapp, for determining the amount of nitrogen in organic bodies: he also says, "we have repeated all the experiments of Dr. Brown on the production of silicon from paracyanogen, but we have not been able to confirm one of his results; what our experiments prove is, that paracyanogen is decomposed by a strong heat into nitrogen gas and a residue of carbon, which is exceedingly difficult of combustion."

To the next Meeting (which was at Manchester, and Dalton was the President of this Section) Dr. Playfair communicated an abstract of Prof. Liebig's report on Organic Chemistry applied to Physiology and Pathology: this abstract is printed in our 'Proceedings;' and the complete work is looked upon as the second part of the report on Organic Chemistry. This Association may therefore fairly consider that it exercised some influence on Liebig in the production of the most important works that he wrote. Playfair's abstract must have been listened to with the greatest interest; and I doubt not the statements made were sharply criticised, especially by the physiologists then at Manchester. Playfair concludes his abstract in these

words, thus summing up the special objects of these reports:—"In the opinion of all, Liebig may be considered a benefactor to his species for the interesting discoveries in agriculture published by him in the first part of this report. And having in that pointed out means by which the food of the human race may be increased, in the work now before us he follows up the chain in its continuation, and shows how that food may best be adapted to the nutrition of man. Surely there are no two subjects more fitted than these for the contemplation of the philosopher; and by the consummate sagacity with which Liebig has applied to their elucidation the powers of his mind, we are compelled to admit that there is no living philosopher to whom the Chemical Section could have more appropriately entrusted their investigation."

At the Meeting at Glasgow in 1855 Liebig was also present; but he then only communicated to this Section a short paper on fulminuric acid, and some remarks on the use of lime-water in the manufacture of bread.

Such, I believe, is the history of the direct relationship which has existed between Liebig and this Association. Indirectly we can hardly recognize how much we owe to him. Interested as he ever was in the work of this Association, I could not but to-day record the instances of direct aid and support which this Section has received from him.

I pass on now to the special subject to which I wish to ask your attention. It is the history of the vegetable colouring-matter found in madder: it has been in use from time immemorial, and is still one of the commonest and most important of dyes; it is obtained from a plant largely cultivated in many parts of the world for the sake of the colour it yields; and the special interest which now attaches to it is that the chemist has lately shown how this natural colouring-matter can be made in the laboratory as well as in the fields—how by using a by-product which formerly was without value, thousands of acres can be liberated for the cultivation of other crops, and the colouring-matter which they formerly produced be cheaper and better prepared in the laboratory or in the manufactory. That a certain colouring-matter could be obtained from the roots of the *Rubia tinctorum* and other species of the same plant has been so long known that apparently no record of its discovery remains. Pliny and Dioscorides evidently allude to it. The former, referring to its value as a dyeing material, says:—"It is a plant little known, except to the sordid and avaricious—and this because of the large profits obtained from it, owing to its employment in dyeing wool and leather." He further says:—"The madder of Italy is the most esteemed, and especially that grown in the neighbourhood of Rome, where and in other places it is produced in great abundance." He further describes it as being grown among the olive-trees, or in fields devoted especially to its growth. The madder of Ravenna, according to Dioscorides, was the most esteemed. Its cultivation in Italy has been continued till the present time; and in 1863 the Neapolitan provinces alone exported it to the value of more than a quarter of a million sterling. At the present day we are all very familiar with this colouring-matter as the commonest that is applied to calicoes: it is capable of yielding many colours, such as red, pink, purple, chocolate, and black. The plant which is the source of this colouring-matter is nearly allied, botanically and in appearance, to the ordinary Galiums or Bedstraws. It is a native probably of Southern Europe as well as Asia. It is a perennial, with herbaceous stem, which dies down every year; its square-jointed stalk creeps along the ground to a considerable distance; and the stem and leaves are rough, with sharp prickles. The root, which is cylindrical, fleshy, and of a pale yellow colour, extends downwards to a considerable depth; it is from this root (which, when dried, is known as madder) that the colouring-matter is obtained. The plant is propagated from suckers or shoots; these require some two or three years to come to full maturity and yield the finest colours, although in France the crop is often gathered after only eighteen months' growth. From its taking so long to develop, it is evidently a crop not adapted to any ordinary series of rotation of crops. The plant thrives best in a warm climate, but has been grown in this country and in the north of Europe.

In India it has been grown from the earliest times, and, as before stated, has been abundantly cultivated in Italy certainly since the time of Pliny; he also

mentions its cultivation in Galilee. In this country its culture has often been attempted, and has been carried on for a short time, but never with permanent success. The madder now used in England is imported from France, Italy, Holland, South Germany, Turkey, and India. In 1857 the total amount imported into this country was 434,056 cwt., having an estimated value of £1,284,989; and the average annual amount imported during the last seventeen years is 310,042 cwt., while the amount imported last year (1872) was 283,274 cwt., valued at £922,244. In 1861 it was estimated that in the South Lancashire district alone 150 tons of madder were used weekly, exclusive of that required for preparing garancine. I quote these figures as showing the magnitude of the industry that we are dealing with. Another point of much interest is the amount of land required for the cultivation of this plant: in England it was found that an acre yielded only from 10 to 20 cwt. of the dried roots; but in South Germany and in France the same amount of land yields about twice that quantity. The madder-cultivator digs up the roots in autumn, dries them, in some cases peels them by beating them with a flail, and exports them in the form of powder, whole root, or after treatment with sulphuric acid, when it is known as Garancine.

The quality of the root varies much; that from the Levant, and known as Turkey-root, is most valued. According, however, to the colour to be produced is the madder from one source or another preferred. To obtain the colouring-matter (which is but very slightly soluble in water) from these roots, they are mixed, after being ground, with water in the dye-vessel, and sometimes a little chalk is added. The fabric to be dyed is introduced, and the whole slowly heated; the colouring-matter gradually passes from the root to the water, and from the water to the mordanted fabric, giving to it a colour dependent of course on the nature of the mordant.

To trace the chemical history of this colouring-matter we have to go back to the year 1790, when a chemist of the name of Watt precipitated the colouring-matter of madder by alum from neutral, alkaline, and acid solutions; he obtained two different colouring-matters, but could not isolate them, and many different shades of colour. Charles Batholdi asserted that madder contained much magnesic sulphate; and Hausmann observed the good effect produced on madder by the addition of calcic carbonate. In 1823 F. Kuhlmann made evidently a careful analysis of the madder-root, and describes a red and a fawn colouring-matter. But the first really important advance made in our knowledge of the chemical constitution of this colouring-matter was by Colin and Robiquet in 1827; they obtained what they believed to be, and what has since really proved to be, the true colouring principle of madder, and obtained it in a state of tolerable purity. Their process for preparing it was very simple: they took Alsace madder in powder, digested it with water, obtained thus a gelatinous mass, which they treated with boiling alcohol, then evaporated off $\frac{1}{5}$ of the alcohol, and treated the residue with a little sulphuric acid to diminish its solubility; then, after washing it with several litres of water, they got a yellowish substance remaining. Lastly, they found that, on moderately heating this product in a glass tube, they obtained a yellowish vapour formed of brilliant particles, which condensed, giving a distinct zone of brilliant needles reflecting a colour similar to that from the native lead chromate. They named this substance alizarin, from the Levant name for madder, *alizari*, the name by which it is still known there.

A few years later we find other chemists attacking this same subject. In 1831 Gaultier de Claubry and J. Persoz published the account of a long research on the subject. They describe two colouring-matters, a red and a rose one: the red one was alizarin; and the rose one was another body nearly allied to it, and now well known as purpurin. Runge also made an elaborate examination of the madder-root; he found no less than five different colouring-matters in it—madder-red, madder-purple, madder-orange, madder-yellow, and madder-brown. The first three he considers to be suited for dyeing-purposes, but not so the last two. Runge's madder-red is essentially impure alizarin, and his madder-purple impure purpurin. He does not give any analysis of these substances.

During the next ten years this subject seems to have attracted but little attention from chemists; but in 1846 Shiel prepared the madder-red and madder-purple

of Runge by processes very similar to those employed by Runge, and analyzed these substances: for madder-red he gives the formula $C_{28}H_{18}O_{9}$, which differs only by H_2O from the formula now adopted; for the madder-purple he gives the formula $C_{28}H_{20}O_{15}$, and for the same substance after being sublimed $C_2H_8O_4$. The chemist who has worked most on this subject, and to whom we are principally indebted for what we know with regard to the different constituents contained in the madder-root, is Dr. Schunck, of Manchester. In Liebig's 'Annalen' for 1848 he gives a long and interesting account of his examination of madder; he isolates and identifies several new substances, which are most important constituents of the root, and has since that time added much to our knowledge of the chemical constitution of madder. In the paper above alluded to he confirms the presence of the alizarin, and gives to it the formula $C_{14}H_{10}O_4$. The principal properties of this body may best be sketched in here. Its volatility and brilliant crystalline appearance have already been mentioned; it is but slightly soluble in cold water, but much more so in alcohol, in ether, and in boiling water. The colour of its solution is yellow; and when it separates out from a liquid it has a yellow flocculent appearance, differing thus greatly from the red, brilliant, crystalline substance before described. In order to obtain this latter body, heat had always been used; so, until the elaborate experiments of Schunck, it was a question whether the heat did not produce a radical change in the substance, whether, in a word, these two bodies were really identical. Schunck's experiments proved that they were, and consequently that this beautiful colouring-matter, alizarin, existed as such in madder. If, however, we go one step further back and examine the fresh root of the *Rubia tinctorum* (that is, as soon as it is drawn from the ground), we shall find no trace of alizarin there. On slicing the root it is seen to be of a light carroty colour, and an almost colourless liquid can be squeezed out of it; but this is entirely free from the colouring-matters of madder. Let the roots, however, be kept, if only for a short time, and then they will give abundant evidence of the presence of alizarin; if simply heated, alizarin may be volatilized from them. It appears, then, that the whole of the tinctorial power of this root is developed after the death of the plant. Schunck explains this curious phenomenon as follows:—In the cells of the living plant there is a substance which he has isolated and has named Rubian; it is easily soluble in water and in alcohol: the solution is of a yellow colour, and has an intensely bitter taste; when dry it is a hard brown gum-like body. It has none of the properties of a dye-stuff; but if we take a solution of it, add some sulphuric or hydrochloric acid to it, and boil, a yellow flocculent substance will slowly separate out, and on filtering it off and washing it, it will be found to have the tinctorial properties of madder, and to contain alizarin. In the liquid filtered from it there is, with the acid added, an uncrystallizable sugar; so that in this way the original product in the root, the rubian, has apparently been split up into alizarin and into sugar. To apply this reaction to what goes on in the root after its removal from the ground, we have to find if any other substances can take the place of the boiling dilute acid; and Schunck has shown there exists in the root itself a substance which is eminently fitted to produce this splitting-up of the rubian. He obtained this decomposing agent from madder simply by digesting it in cold water and adding alcohol to the liquid; this threw down a reddish flocculent substance; and if only a small portion of this was added to an aqueous solution of the rubian and allowed to stand for a few hours in a warm place, it was found that the rubian was gone, and in place of it there was a thick tenacious jelly; this, treated with cold water, gave to it no colour, no bitter taste, but much sugar. From the jelly remaining insoluble, alizarin could be extracted; in fact, of all known substances this very one found in the madder itself is best suited for effecting this decomposition of the rubian.

It has long been known to dyers that the amount of colouring-matter in madder will increase on keeping it; even for years it will go on improving in quality: and an experiment of Schunck's shows that the ordinary madder, as used by the dyer, has not all the rubian converted into colouring-matter; for on taking a sample of it and extracting with cold water, he got an acid solution devoid of dyeing properties; but on allowing this solution to stand some time it gelatinized, and then possessed dyeing properties.

It appears, then, that there must exist in the root two substances kept apart during the life of the plant in some way of which we know nothing; but as soon as it dies they begin slowly to act on one another, developing thus the colouring-matters in madder.

Coincident with the appearance of Schunck's first paper was one by Debus on the same subject. He looked upon alizarin as a true acid, and gave it the name of lizaric acid; but, as far as the composition of it was concerned, the percentage numbers he obtained agreed closely with those given by Schunck. One other investigation concludes all that is important in the history of alizarin as obtained from madder. This last investigation is of great interest; it was by Julius Wolff and Adolphe Strecker, and published in 1850. They confirm the results of others so far, that there are in the madder-root two distinct colouring-substances, this important one alizarin, and the other one purpurin. They prepare these colouring-matters much in the same way that Schunck did, and very carefully purify and analyze them. The formulæ which they give for them differ, however, from Schunck's: for alizarin they give the formula $C_{20}H_{12}O_{6}$, and for purpurin $C_{18}H_{12}O_{6}$; further, they suggest that, by the process of fermentation, the former is converted into the latter; and they show that by oxidation they both yielded phthalic acid. Since the publication of this research, until the last year or two, this formula for alizarin has been generally adopted by chemists; and in most modern books we find it given as expressing the true composition of that body. It was not only the careful and elaborate work which they devoted to the subject, but also the ingenious and apparently well-founded theory on the subject which carried conviction with it. Laurent had shown, not many years before, that when naphthalin, that beautiful and white crystalline substance obtained from coal-tar, was acted on by chlorine and then treated with nitric acid, a body known as chlornaphthalic acid, and having the composition $C_{20}H_{10}Cl_2O_6$, was obtained; and on comparing this formula with the one they had obtained for alizarin, Wolff and Strecker at once concluded that it really was alizarin, only containing two atoms of chlorine in place of two of hydrogen; make this replacement, an operation generally easily performed, and from naphthalin they had prepared alizarin. Further, this relationship between chlornaphthalic acid and alizarin is borne out in many ways: it, like alizarin, has the power of combining with different basic substances, has a yellow colour, is insoluble in water, melts at about the same temperature, is volatile, and when acted on by alkalies gives a strongly coloured solution. Taking, then, all these facts into consideration, can we wonder that these chemists feel convinced that they have established the composition of alizarin, and have shown the source from which it is to be obtained artificially? Apparently but one very simple step remains to crown their work with success, that of replacing the chlorine by hydrogen. Melsens had only shortly before shown how this substitution could easily be made in the case of chloracetic acid, by acting on it with potassium amalgam; and Kolbe had used the battery for the same purpose: both these processes, and doubtless all others that the authors can think of, are tried upon the chlornaphthalic acid; but chlornaphthalic acid it remains, and they are obliged to confess they are unable to make this substitution; still they are strong in the belief that it is to be done and will be done, and conclude the account of their researches by pointing out the great technical advantage will be the getting alizarin from a worthless substance such as naphthalin. One cannot help even now sympathizing with these chemists in their not being able to confirm what they had really the strongest evidence for believing must prove to be a great discovery. We now know, however, that had they succeeded in effecting this substitution, or had they in any other way obtained this chlornaphthalic acid without the chlorine, if I may so speak of it, which since their time has been done by Martius and Griess, alizarin would not have been obtained; but a body having a remarkable parallelism in properties to it would have been. This body, like alizarin, is of a yellowish colour, but slightly soluble in water, easily in alcohol and in ether, is volatile, and on oxidation yields the same products; it is, in fact, an analogous body but belonging to another group. We also now know that the formula proposed by Wolff and Strecker, and so long in use, is not the correct one. But little more remains to be added with regard to the history of alizarin, as gathered rom the study of the natural substance. Schutzenberger and Paraf suggested

doubling Wolff and Strecker's formula for alizarin; and Bolley suggested the formula $C_{20}H_{13}O_6$, which, owing to the uneven number of hydrogen atoms, was soon rejected. If we compare our present knowledge of alizarin with what it was when these researches on the natural product were completed, it is as light compared with darkness; and we may well ask, whence has come this influx of knowledge? The answer, I hope to show you, is undoubtedly that it has come from the careful and accurate study of abstract chemistry. I know of no history in the whole of chemistry which more strikingly illustrates how the prosecution of abstract science lays the foundation for great practical improvements than the history of alizarin does.

My object now is, then, to show you, as shortly as I can, how by indirect means the composition of alizarin was discovered, how it has been built up artificially, and how it is superseding for manufacturing-purposes the long-used natural product.

To trace this history from its source we must go back to 1785, when an apothecary of the name of Hofmann obtained the calcium salt of an acid called quinic acid from Cinchona-bark. This acid is now known to be of common occurrence in plants; it exists in the bilberry and in coffee, in holly-, ivy-, oak-, elm-, and ash-leaves, and probably many other leaves. Liebig also prepared the calcium salt, and was the first to give a complete analysis of it; the formula he gave for it was $C_{15}H_{24}O_{12}$. Baup, on repeating Liebig's experiments, arrived at a somewhat different conclusion, and gave the formula $C_{15}H_{20}O_{10}$. In 1835, at Liebig's suggestion to determine which formula was correct, Alexander Woskrensky, from St. Petersburg, then a student at Giessen, undertook the further investigation of this subject, and established the formula $C_{14}H_{24}O_{12}$, the one in fact now in use. In the course of this investigation, which he carried further than merely settling the percentage composition of this acid, he describes what to us now is of most interest, a new substance having peculiar and very marked properties. He says that when a salt of quinic acid is burnt at a gentle heat he gets aqueous vapour, the vapour of formic acid, and a deposit of golden needles, which are easily sublimed. Afterwards he describes how this same golden substance may be obtained from any salt of quinic acid by heating it with manganic dioxide and dilute sulphuric acid; it then distils over, condensing in golden-yellow needles on the sides of the receiver, and may be rendered pure by resublimation. The composition of this body he finds to be C_3H_2O, and names it quinoyl, a name strongly objected to by Berzelius, as conveying a wrong impression of the nature of the body; he proposed in place of it the name quinone, by which it is still known. Far as this body would seem to be removed from alizarin, yet it is the study of its properties which led to the artificial production of alizarin.

Some years afterwards Wöhler also examined the decomposition of quinic acid; he prepares again this quinone, and follows exactly the process described by Woskrensky: he states that, with regard to the properties of this remarkable body, he has nothing particular to add; however, he proposes a different formula for it, and discovers and describes other bodies allied to it; among these is hydroquinone, $C_6H_6O_2$. Laurent afterwards shows that the formula proposed by Wöhler is inconsistent with his and Gerhardt's views, and by experiment confirms the former formula for this body. Although many other chemists devoted much attention to this substance, still its real constitution and relation to other compounds remained long unknown. Thus Wöhler, Laurent, Hofmann, Städeler, and Hesse all had worked at it; and much experimental knowledge with regard to it had been acquired. One important point in its history was, first, the discovery of chloranil by Erdmann in 1841, and then Hofmann showing that, by heating quinone with potassic chlorate and hydrochloric acid, chloranil could be obtained from it—that, in fact, chloranil was quinone in which all the hydrogen had been replaced by chlorine. Perhaps the most general impression among chemists was, that in constitution it was a kind of aldehyde; certainly its definite place among chemical compounds was not known. Kekulé suggests a rational formula for it; but it is to Carl Graebe that we owe our knowledge of its true constitution. In 1868 he published a remarkable and very able paper on the quinone group of compounds, and then first brought forward the view that quinone was a substitution-

derivative of the hydrocarbon benzol (C_6H_6). On comparing the composition of these two bodies, it is seen that the quinone contains two atoms of oxygen more and two atoms of hydrogen less than benzol; and Graebe, from the study of the decomposition of quinone and from the compounds it forms, suggested that the two atoms of oxygen form in themselves a group which is divalent, and thus replace the two atoms of hydrogen; this supposition he very forcibly advocates, and shows its simple and satisfactory application to all the then known reactions of this body. This suggestion really proved to be the key, not only to the explanation of the natural constitution of quinone and its derivatives, but to much important discovery besides.

At this time quinone seemed to stand alone; no other similarly constituted body was known to exist; but what strikingly confirms the correctness of Graebe's views, and indicates their great value, is that immediately he is able to apply his lately gained knowledge, and to show how really other analogous bodies, other quinones in fact, already exist. He studied with great care this quinone series of compounds and the relation they bore to one another—the relation the hydrocarbon benzol bore to its oxidized derivative quinone, and its relation to the chlorine substitution-products derivable from it. At once this seems to have led Graebe to the conclusion that another such series already existed ready formed, and that its members were well known to chemists—that, in fact, naphthalin ($C_{10}H_8$) was the parent hydrocarbon, and that the chloroxynaphthalin chloride ($C_{10}H_4Cl_2O_2$) and the perchloroxynaphthalin chloride ($C_{10}Cl_6O_2$) were really chlorine substitution-compounds of the quinone of this series, corresponding to the bichloroquinone and to chloranil—that the chloroxynaphthalic acid, $C_{10}H_4Cl(HO)O_2$, and the perchloroxynaphthalic acid, $C_{10}Cl_5(HO)O_2$, all compounds previously discovered by Laurent, were really bodies belonging to this series—and, further, that the supposed isomer of alizarin discovered by Martius and Griess was really related to this last compound, having the composition $C_{10}H_5(HO)O_2$. Further, he was able to confirm this by obtaining the quinone itself of this series, the body having the formula $C_{10}H_6(O_2)''$, containing also two atoms less of hydrogen and two atoms more of oxygen than the hydrocarbon naphthalin; and to this body he gave the characteristic name of naphthoquinone. The chlorine compounds just named are, then, chlornaphthoquinones or chloroxynaphthoquinones, and correspond to the former chloroquinones; and Martius and Griess's compound will be an oxynaphthoquinone: many other compounds of this series are also known. Another step confirmatory of this existence of a series of quinones was made by Graebe and Bergmann: as the chloranil could be found by treating phenol with potassic chlorate and hydrochloric acid, and quinone derived from it, they showed that in the next higher series to the phenol series, viz. with cresol, the same reaction held good; and by treating it in the same way, they obtained a di- and a trichlorotoluquinone, $C_6\left\{\begin{matrix}CH_3\\(O_2)''\\Cl_2\\H\end{matrix}\right.$, $C_6\left\{\begin{matrix}CH_3\\(O_2)''\\Cl_3\end{matrix}\right.$, which in physical properties very closely resembled the corresponding compounds in the lower series: other compounds have also been prepared.

In the next step we have the application which connects these series of discoveries with alizarin. Following the clue of a certain analogy which they believed to exist between the chloranilic acid $\left(C_6Cl_2\begin{matrix}(O_2)''\\(HO)_2\end{matrix}\right)$ and the chloroxynaphthalic acid $\left(C_{10}H_4Cl\begin{matrix}(O_2)''\\HO\end{matrix}\right)$, which they had proved to be quinone compounds and alizarin, believing that a certain similarity of properties indicated a certain similarity of constitution, Graebe and Liebermann were led to suppose that alizarin must also be a derivative from a quinone, and have the formula $\left(C_{14}H_4\begin{matrix}(O)_2\\(HO)_2\end{matrix}\right)$. This theory they were able afterwards to prove. The first thing was to find the hydrocarbon from which the quinone might be derived. This was done by taking alizarin itself and heating it with a very large excess of zinc powder in a long tube, closed at one end. A pro-

duct distilled over, and condensed in the cool part of the tube. On collecting it and purifying it by recrystallization, they found they had not a new substance, but a hydrocarbon discovered as long ago as 1832 by Dumas and Laurent, and obtained by them from tar. They had given it the formula $C_{15}H_{12}$; and as apparently it thus contained once and a half as many atoms of carbon and hydrogen as naphthalin did, they named it Paranaphthalin. Afterwards Laurent changed its name to Anthracene, by which it is still known. Fritzsche, in 1857, probably obtained the same body, but gave it the formula $C_{14}H_{10}$. Anderson also met with it in his researches, established its composition, and formed some derivatives from it. Limprich in 1866 showed it could be formed synthetically by heating benzol chloride (C_7H_7Cl) with water; and Berthelot has since proved that it is formed by the action of heat on many hydrocarbons. This first step was then complete and most satisfactory: from alizarin they had obtained its hydrocarbon; and this hydrocarbon was a body already known, and with such marked properties that it was easy to identify it. But would the next requirement be fulfilled? would it, like benzol and naphthalin, yield a quinone? The experiment had not to be tried; for when they found that anthracene was the hydrocarbon formed, they recognized in a body already known the quinone derivable from it. It had been prepared by Laurent by the action of nitric acid on anthracene, and called by him Anthracenuse; and the same substance was also discovered by Anderson, and called by him Oxanthracene. The composition of this body was proved by Anderson and Laurent to be $C_{14}H_8O_2$, and thus bears the same relation to its hydrocarbon anthracene that quinone and naphthaquinone do to their hydrocarbons. Graebe gave to it the systematic name of Anthraquinone.

We have, then, now three hydrocarbons (C_6H_6, $C_{10}H_8$, and $C_{14}H_{10}$) differing by C_4H_2, and all forming starting-points for these different quinone series. Anthraquinone, acted upon by chlorine, gave substitution-products such as might have been foretold. It is an exceedingly stable compound, not acted upon even by fusion with potassic hydrate. Bromine does not act upon it in the cold; but at 100° it forms a bibromanthraquinone. Other bromine compounds have also been formed.

Now, if the analogies which have guided them so far still hold good, they would seem to have the means of forming alizarin artificially. Their theory is that it is dioxyanthraquinone $\left(C_{14}H_6\begin{matrix}(O_2)''\\(HO)_2\end{matrix}\right)$, and if so, judging from what is known to take place with other quinone derivatives, should be formed from this dibromanthraquinone on boiling it with potash or soda and then acidulating the solution. They try the experiment, and describe how, contrary at first to their expectation, on boiling dibromanthraquinone with potash no change occurred; but afterwards, on using stronger potash and a higher temperature, they had the satisfaction of seeing the liquid little by little become of a violet colour. This shows the formation of alizarin. Afterwards, on acidifying this solution, the alizarin separated out in yellowish flocks. On volatilizing it they get it in crystals like those obtained from madder; on oxidizing it with nitric acid, they get phthalic acid; and on precipitating it with the ordinary mordants or other metallic solutions, they get compounds exactly comparable to those from the natural product. Every trial confirms their success; so, by following purely theoretical considerations, they have been led to the discovery of the means of artificially forming this important organic colouring-matter. A special interest must always attach itself to this discovery; for it is the first instance in which a natural organic colouring-matter has been built up by artificial means. Now the chemist can compete with nature in its production. Although the first, it is a safe prediction that it will not long be the only one. Which colouring-matter will follow next it is impossible to say; but, sooner or later, that most interesting one, scientifically and practically, indigo, will have to yield to the scientific chemist the history of its production.

Returning for a moment to the percentage composition of alizarin, now that we know its constitution, its formula is established; and on comparing it ($C_{14}H_8O_4$) with all the different formulæ which have been proposed, we see that the one advocated by Schunck was most nearly correct—in fact that it differs from it only by two atoms of hydrogen. It is not without interest to note that the next most im-

portant colouring-matter in madder, purpurin, which so pertinaciously follows alizarin, is in constitution very nearly allied to it, and is also an anthracene derivative.

Scientifically, then, the artificial production of this natural product was complete; but the practical question, Can it be made in the laboratory cheaper than it can be obtained from the root? had yet to be dealt with. The raw material, the anthracene, a by-product in the manufacture of coal-gas, had as yet only been obtained as a chemical curiosity; it had no market value; its cost would depend on the labour of separating it from the tar and the amount obtainable. But with regard to the bromine necessary to form the bibromanthraquinone it was different; the use of such an expensive reagent would preclude the process becoming a manufacturing one. But could no cheaper reagent be used in place of the bromine, and thus crown this discovery by utilizing it as a manufacturing process? It was our countryman Mr. Perkin who first showed how this could be done, and has since proved the very practical and important nature of his discovery by carrying it out on the manufacturing scale. The nature of Perkin's discovery was the forming, in place of a bibromanthraquinone, a disulphoanthraquinone; in a word, he used sulphuric acid in place of bromine, obtaining thus a sulpho-acid in place of a bromine substitution-compound. The property of these sulpho-acids, containing the monovalent group HSO_3, which is the equivalent to the atom of bromine, is that on being boiled with an alkali they are decomposed, and a corresponding alkaline salt formed. Thus the change from the anthraquinone to the alizarin was effected by boiling it with sulphuric acid. At a high temperature it dissolves, becoming a sulpho-acid, $C_{14}H_6\left\{\begin{matrix}(O_2)''\\ HSO_3\\ HSO_3\end{matrix}\right.$; and then the further changes follow, as they did with the bromine compound. The sulpho-acid boiled with potash is decomposed, and a potash salt of alizarin and potassic sulphite are formed; acid then precipitates the alizarin as a bright yellow substance.

While Perkin was carrying on these researches in this country, Caro, Graebe, and Liebermann were carrying on somewhat similar ones in Germany; and in both countries have the scientific experiments developed into manufacturing industries. My knowledge extends only to the English manufactory; and if any excuse be necessary for having asked your attention to-day to this long history of a single substance, I think I must plead the existence of that manufactory as my excuse; for it is not often that purely scientific research so rapidly culminates in great practical undertakings. Already has the artificial become a most formidable opponent to the natural product; and in this struggle, already begun, there can be no doubt which will come off victorious.

In the manufactory is rigidly carried out the exact process I have already described to you. In tar there is about one per cent. of anthracene; this, in a crude impure state, is obtained from it by the tar-distiller and sent by him to the colour-works. Here it is purified by pressure, by dissolving from it many of its impurities, and, lastly, by volatilizing it. Then comes the conversion of it into the anthraquinone by oxidizing agents, nitric or chromic acid being used, then the formation of the sulpho-compound by heating it with sulphuric acid to a temperature of about 260° C. The excess of acid present is then neutralized by the addition of lime, and the insoluble calcic sulphate is filtered off. To the filtered liquid sodic carbonate is added, and thus the calcic salt of the sulpho-acid is changed into the sodic salt, $C_{10}H_6\left\{\begin{matrix}(O_2)''\\ NaSO_3\\ NaSO_3\end{matrix}\right.$. This is afterwards heated to about 180° C. with caustic soda, thus decomposing the sulpho-acid and forming the soda salt of alizarin and the sodic sulphite. The alizarin salt so formed remains in solution, giving to the liquid a beautiful violet colour. From this solution sulphuric acid precipitates the alizarin as an orange-yellow substance. It is allowed to settle in large tanks, and then is run, in the form of a yellowish mud, which contains either 10 or 15 per cent. of dry alizarin, into barrels, and is in this form sent to the print-works, and used much in the same way as the original ground madder was used.

This alizarin mud, as I have called it, containing but 10 per cent. of dry alizarin,

is equal in dyeing-power to about 8 times its weight of the best madder, and is the pure substance required for the dyeing, in place of a complicated mixture containing certain constituents which have a positively injurious effect on the colours produced.

The scientific knowledge and energy which Mr. Perkin has brought to bear on the manufacture of this colouring-matter seem already to have worked wonders. The demand and supply for artificial alizarin are increasing at a most rapid rate; and yet the manufacture of it seems hardly to have commenced. The value of madder has much decreased; and in fact, judging by what occurred in the year of revolution and commercial depression (1848), when the price of madder fell for a time to a point at which it was considered it would no longer remunerate the growers to produce it, that point has now been again reached, but certainly from very different reasons. Last year * artificial alizarin equal in value to about one fourth of the madder imported into England was manufactured in this country. This year the amount will be much larger.

Thus is growing up a great industry, which, far and wide, must exercise most important effects. Old and cumbrous processes must give way to better, cheaper, newer ones; and, lastly, thousands of acres of land in many different parts of the world will be relieved from the necessity of growing madder, and be ready to receive some new crop. In this sense may the theoretical chemist be said even to have increased the boundaries of the globe.

On the Detection of Adulteration of Tea. By ALFRED H. ALLEN, *F.C.S.*

On Alpha- and Beta-Naphthylic Sulphide.
By HENRY E. ARMSTRONG, *Ph.D., F.C.S.*

Whereas in the fatty series of organic compounds two classes of bodies of the form R'(SCN) are known, viz. the sulphocyanates and the so-called mustard-oils or isosulphocyanates, in the aromatic series the compounds of the latter class alone have been obtained. Thus all attempts to prepare phenylic sulphocyanate, for example, by distilling a salt of benzenesulphonic acid with potassic sulphocyanate have been unsuccessful. It appeared possible that the desired compound, although formed in the first instance, was produced at a temperature so high that it at once underwent decomposition, and that better results might be hoped for from the employment of sulpho-salts more easily acted upon than the benzenesulphonates. A dry mixture of the potassic salt of alpha-naphthalenesulphonic acid and potassic sulphocyanate was therefore submitted to distillation; and a semisolid product was thus obtained, which could be purified by recrystallization from a solution of carbonic disulphide in alcohol. On analysis numbers were obtained which show that the product is a *naphthylic sulphide*, $(C_{10}H_7)_2S$. A mixture of the potassic salt of beta-naphthelenesulphonic acid and potassic sulphocyanate behaved similarly on distillation; the product appears to consist of beta-naphthylic sulphide.

Alpha-naphthylic sulphide crystallizes in long white needles, melting at about 100°; it is scarcely soluble in alcohol, but dissolves readily in carbonic disulphide and glacial acetic acid. The beta-compound has a higher melting-point, and is also less soluble in a mixture of carbonic disulphide and alcohol.

On distilling the potassic salt of either alpha- or beta-naphthalenesulphonic acid much naphthalene is formed, but apparently no naphthylic sulphide.

On the Action of Sulphuric acid on Ethylaniline and Dimethylaniline.
By HENRY E. ARMSTRONG, *Ph.D., F.C.S.*

On heating ethylaniline with an excess of Nordhausen sulphuric acid until sulphurous hydride is evolved, and subsequently mixing the product with water, a

* On the 1st of this month (September) the value of madder-roots in France was 24 to 26 francs per 50 kilogrammes. The average price in 1848 was 27, but in June and July of that year it was 22 francs.

crystalline mass is obtained, which is readily recognized as sulphanilic acid. The reaction probably occurs thus:

$$N \begin{cases} C_6H_5 \\ C_2H_5 \\ H \end{cases} + 2\,H_2SO_4 = N \begin{cases} C_6H_4\,(HSO_3) \\ H \\ H \end{cases} + C_2H_5.HSO_4 + OH_2.$$

Dimethylaniline similarly treated behaves differently, however, being converted into a monosulphonic acid.

$$N \begin{cases} C_6H_5 \\ CH_3 \\ CH_3 \end{cases} + H_2\,SO_4 = N \begin{cases} C_6H_4\,(HSO_3) \\ CH_3 \\ CH_3 \end{cases} + OH_2.$$

Note on Cresol Derivatives. *By* HENRY E. ARMSTRONG, *Ph.D., F.C.S.*

The author briefly referred to the results of the preliminary examination of coal-tar cresylic acid, which he had commenced in conjunction with Mr. C. L. Field, and stated that the dinitrocresol described by them in a communication to the Chemical Society had since been identified with dinitroparacresol.

On the Action of Sulphide of Methyl on Bromacetic Acid.
By Professor Dr. CRUM BROWN, *F.R.S.E.*

On Black Deposits of Metals. *By* Dr. J. H. GLADSTONE, *F.R.S.*

If one metal be thrown down from solution by means of another metal, it does not always present itself of the same colour as it exhibits when in mass; in fact most metals that are capable of being precipitated by substitution may be obtained in a black condition. The allied metals platinum, palladium, and iridium are generally, if not always, black when thus prepared; and bismuth and antimony form black fringes, and little else. Similar fringes are also formed by gold; but it also yields green, yellow, or lilac metal according to circumstances. Copper when first deposited on zinc, whether from a weak or a strong solution, is black; but in the latter case it becomes chocolate-coloured as it advances, or red if the action be more rapid. Lead in like manner is always deposited black in the first instance, though the growing crystals soon become of the well-known dull grey. Silver and thallium appear as little bushes of black metal on the decomposing plate, if the solution be very weak, otherwise they grow of their proper colour. Zinc and cadmium give a black coating, quickly passing into dark grey, when their weak solutions are decomposed by magnesium. The general result may be stated thus:—If a piece of metal be immersed in the solution of another metal which it can displace, the latter metal immediately makes its appearance at myriads of points in a condition that does not reflect light; but as the most favourably circumstanced crystals grow they acquire the optical properties of the massive metal, the period at which the change takes place depending partly on the nature of the metal, and partly on the rapidity of its growth.

In the production of the black deposit of the copper-zinc couple lately employed by the author and Mr. Tribe to break up various compound bodies, there are several stages that may be noted. At first an outgrowth of copper forms on the zinc; then while this action is still proceeding the couple itself acts upon the water or the sulphate of zinc in solution, the metallic zinc being oxidized, and hydrogen gas or black zinc being formed against the copper branches. This deposit of zinc was originally observed by Dr. Russell. The arrangement of the particles between the two metals in connexion is supposed to be somewhat thus:—

$$Cu \mid Zn\,SO_4 \mid Zn\,SO_4 \mid H_2O \mid H_2O \mid Zn,$$

which by the conjoint polar and chemical force becomes

$$Cu \mid Zn \mid Zn\,SO_4 \mid H_2\,SO_4 \mid H_2O \mid Zn\,O.$$

If there is still copper sulphate in the solution, this deposited zinc may in its turn become coated with copper; but if it remain exposed to water it is sure to become oxidized. The black deposit often assumes a brownish colour when this is the case. The copper on which zinc has been deposited gives a brassy streak when rubbed in a mortar; but the presence of oxides tend to prevent the sticking together of the detached pieces of metal, and thus the formation of a streak on pressure. If, however, the oxide be removed by acetic acid, the clean ramifications of metal, whether black or otherwise, conglomerate of their own accord in a remarkable way, and little pressure is required to obtain a yellowish metallic streak; while, if hydrochloric acid be used, the zinc itself also dissolves with effervescence, and the conglomerating pieces of metal when rubbed give a coppery streak.

On a Continuous Process for Purifying Coal-gas and obtaining Sulphur and Ammonium Sulphate. By A. VERNON HARCOURT, *F.R.S.*, *and* F. W. FISON, *F.C.S.*

On the Spectra of certain Boric and Phosphoric Acid Blowpipe Beads. *By* CHARLES HORNER.

This memoir is intended to show the importance of studying coloured phosphoric and boric acid beads with the spectroscope, and that much valuable knowledge may be derived from a careful observation of the various spectra, since certain constituents in complex minerals may be often recognized in the same bead. The author then explains how in phosphoric acid beads didymium, uranium, cobalt, chromium, &c. may be detected in fractional quantities by their characteristic absorption-bands and lines in the presence of other substances like iron, nickel, &c., which give no such positive spectra.

The author also furnishes new tests for tungsten, molybdenum, and cadmium, by which the *two* former more especially may be determined in infinitesimal quantities of at least 0·0001 of a grain by means of their remarkable absorption-spectra. To produce these results the author adopts the somewhat novel method of fusing the substance along with boric acid simultaneously, at a very gentle heat, until the bead is tolerably clear. Tungsten, molybdenum, vanadium, and titanium oxides all yield brown beads when cold, nickel reddish purple, and cadmium a bright yellow by reflected light.

The subjoined Table gives the positions of the bands and lines according to Mr. Sorby's scale and notation.

TABLE OF SPECTRA.

Phosphoric acid beads.	*Red end.*
Uranium oxide	$1\ \overline{1}\frac{1}{4},\ \dot{1}\frac{3}{4},\ \dot{2}\frac{3}{8},\ \dot{3}\frac{5}{8},\ \overbrace{\dot{5}\frac{1}{8},\ \dot{5}\frac{3}{8}},\ 7\frac{3}{8}.$
Chromium „	$\frac{3}{4}\ \overbrace{1\frac{1}{4},\ 1\frac{1}{2}},\ \dot{2}\frac{3}{8}.$
Didymium „	$\overbrace{3\frac{5}{8}\ 4\frac{1}{8}}\qquad 6,\ 6\frac{1}{2},$
Tungsten „	3 5
Molybdenum oxide	$3\frac{3}{4}$ .... $6\frac{3}{8}$
Boric acid beads.	
Tungsten oxide	$\bar{2}\frac{1}{4}\ \ 5\frac{1}{4}$......
„ with soda	$\bar{1}\frac{1}{4}\ \ 3\ \ 5\frac{1}{4}$......
Molybdenum oxide	$\dot{1}\frac{3}{8}\ \dot{2}\frac{5}{8}\ \ 5\frac{1}{4}$......
Cadmium „	$\dot{6}\frac{3}{4}$......

Note on the Elements in the Sun. *By* J. Norman Lockyer, *F.R.S.*

The Sewage of Manufacturing Towns. *By* W. T. McGowen.

The subject one of greatest difficulty in the management of large manufacturing towns; importance of having it considered before the Association.

Sketch of the stages by which the question has attained its present magnitude. Absurd position of local authorities consequent on conflicting decisions to which they are exposed.

Endeavours on the part of Government to arrive at satisfactory result by means of Commissions; their result.

Proceedings of Government by bill in the Commons; review of the measure; renewed bill in the Lords; review thereof. Result of both bills.

Return by Local Government Board as to steps taken in towns to deal with sewage. Review of the document.

Measures adopted by the Bradford Corporation for defecating their sewage. However successful, will be comparatively inappreciable as affecting the state of the Aire and Calder.

Combined efforts of Bradford and neighbouring Corporations to deal with those rivers on a broad and liberal principle by means of an elective Conservancy Board for the rivers, and by means of the Local Authority in every district of the Watershed; subject to appeal to the Local Government Board. Defeat of the measure, though supported by the Government recommendation that the leading feature of that scheme be adopted as the basis of general legislation.

Difficulty of establishing sewage-farms in this and similar districts.

Possibility of failure of all remedies yet tried. Outline of scheme for such an emergency.

On the Valuation of Commercial Crude Anthracene. *By* Dr. Paul *and* A. D. Cownley, *F.C.S.*

On several Homologues of Oxaluric Acid. *By* W. H. Pike.

The anhydrides of the dibasic acids add themselves to urea, and to sulpho-carbamide to form acids which are homologous with oxaluric acid. Thus, by heating a mixture of succinic anhydride and urea in the proportion of their molecular weights to 130° C., the succino-carbaminic acid is produced, as expressed by the equation

$$\begin{array}{l} CH_2\text{—}CO \\ \vert \qquad\quad \rangle O \\ CH_2\text{—}CO \end{array} + CO\begin{array}{l} \diagup NH_2 \\ \\ \diagdown NH_2 \end{array} = \begin{array}{l} CH_2\text{—}CO\text{—}NH\text{—}CO\text{—}NH_2 \\ \vert \\ CH_2\text{—}COOH. \end{array}$$

This acid, crystallized from water, forms pearly scales which fuse at 203–204° C. It is insoluble in alcohol, ether, chloroform, and bisulphide of carbon, but soluble in glacial acetic acid and boiling water, as also in concentrated sulphuric acid. The salts of the alkalies and alkaline earths are easily soluble; those of lead and silver form white precipitates.

If sulpho-carbamide be substituted for urea in the above reaction, the succino-sulphocarbaminic acid is formed. This acid resembles the preceding in all its properties. It forms a crystalline powder, which fuses at 210·5–211° C. Its formula is

$$\begin{array}{l} CH_2\text{—}CO\text{—}NH\text{—}CO\text{—}NH_2 \\ \vert \\ CH_2\text{—}COOH \end{array} .$$

Citraconic anhydride does not combine with urea; carbonic acid is liberated, and

citraconamide produced. However, citraconic anhydride treated with sulphocarbamide yields the citraconsulpho-carbaminic acid

$$C_3H_4\begin{cases}CO—NH—CO—NH_2\\COOH\end{cases}.$$

This body has similar properties to those of the foregoing acids. It fuses at 222-223° C. No such combination could be obtained between lactide and urea, or between lactide and sulphocarbamide. In the first case lactamide and carbonic acid were produced; in the second, lactamide and oxysulphide of carbon.

On Horn Silver. *By* W. Chandler Roberts, *F.C.S.*

On the Constitution of some Silicates. *By* Professor Schafarik, *Prague.*

On Artificial Magnetite. *By* John Spiller, *F.C.S.*

The object of this communication was to point out an error in the statement of a chemical reaction occurring in several standard works of reference, and, in the second place, to indicate the formation of crystallized magnetic oxide of iron (magnetite) in the ordinary process of manufacturing aniline from nitrobenzol by the reducing action of metallic iron.

Reference was made to Reimann's 'Aniline and its Derivatives,' and to Wagner's 'Chemical Technology,' where the action of iron upon nitrobenzol in the presence of acid (Béchamp's process) is stated to give ferric oxide or a "hydrated oxide of iron." The author pointed to the fact that the ordinary residual product in this operation was *black*, and could be so far purified by washing and elutriation from the excess of iron usually remaining in admixture as to give a fine black pigment, which appeared under the microscope as minute octahedra, and was strongly magnetic. Chemical analysis showed this to consist almost entirely of magnetic oxide of iron, with such impurities as were inherent to the process or previously existed in the cast iron. The physical properties of this form of oxide were further described, and its analogy to the native varieties of magnetic ore (Cornish and Dannemora) shown by the following analysis of the substance dried at 110° C.:—

Ferric oxide	67·00
Ferrous oxide	30·05
Graphite	1·23
Silica	·78
Phosphoric acid	·62
Sulphur and manganese	traces
	99·68
Metallic iron (total)	70·27

On a form of Gas-generator. *By* C. J. Woodward, *B.Sc.*

What are required in a gas-generator are a ready means of bringing the acid into contact with the zinc, marble, &c., and, what is of even greater importance, a ready means of removing it when the supply of gas is no longer wanted. The generator devised by Dobereiner is theoretically perfect; but, owing to slight leakage, it will not remain in action for any length of time.

Two forms of generator were described. The first consists of a stoneware vessel somewhat similar to a Woulfe's bottle. To one of the tubulures is fastened a glass cylinder containing the zinc, marble, &c.; to the other tubulure is attached a tube through which a plug of wood passes loosely. To bring the apparatus into action

the wooden plunger is depressed, when, from displacement, the acid rises and is thus brought into contact with the zinc. When the plug is down the supply of gas is self-regulating, just as in the apparatus of Dobereiner. The other form of generator, and the one which the author generally uses, is made from a wide-mouthed bottle containing acid. Into the mouth of this bottle fits a glass cylinder containing the materials for generating the gas. At the shoulder of the bottle is a hole admitting a small india-rubber tube, on which is placed a pinch-tap.

Supposing the apparatus is wanted in action, the pinch-tap is opened and air forced into the bottle by means of the mouth. The pressure of air forces acid up the cylinder, when immediately the gas is given off. The apparatus is put out of action in a moment by opening the pinch-tap, when the confined air escapes and the acid falls. Instead of using the mouth to compress the air, a small india-rubber ball may be used.

New Derivatives from Codeine and Morphine. By C. R. A. Wright, *D.Sc. Lond., Lecturer on Chemistry in St. Mary's Hospital, London.*

Since the last Meeting of the Association the following further results have been obtained, partly in conjunction with Mr. E. L. Mayer, of Glasgow.

Some of the polymerides of morphine corresponding to the di-, tri-, and tetra-codeine described in last year's paper are obtainable by the action of sulphuric acid diluted with its own bulk of water on morphine at 100°. Although dicodeine is readily obtainable from codeine in this way, *dimorphine* does not appear to result in any appreciable quantity; *trimorphine* and *tetramorphine*, on the other hand, are readily producible, the physical properties of these two bases and their derivatives corresponding exactly with those of tricodeine and tetracodeine respectively. The derivatives of the four series of polymerides may be thus characterized:—

Mono-series (non-polymerized). Bases crystalline; salts crystalline.
Di-series (polymerized). Bases amorphous and soluble in ether; salts crystalline.
Tri-series (polymerized). Bases amorphous and soluble in ether; salts amorphous.
Tetra-series (polymerized). Bases amorphous and insoluble in ether; salts amorphous.

On account of their physical properties, the bases hitherto provisionally termed "apomorphine," "deoxycodeine," and "deoxymorphine" are viewed as being derivatives of (hypothetical) dimorphine or of dicodeine respectively.

Trimorphine, when administered subcutaneously to cats, produces excitement and salivation, with slight hypnotesia, but no vomiting; tetramorphine, on the other hand, is a most energetic emetic, its action being (so far as cats are concerned) much more marked than even that of "apomorphine."

Trimorphine is acted on by hydrochloric acid, producing a chlorinated base; in this respect trimorphine is not analogous to tricodeine, which only loses the elements of water by this treatment; thus,

$$\text{Tricodeine} \ldots\ldots\ldots \bar{C}_3 = 6H_2O + (\bar{C}_3 - 6H_2O),$$
$$\text{Trimorphine} \ldots\ldots \bar{M}_3 + 2HCl = 2H_2O + (\bar{M}_3 + 2HCl - 2H_2O).$$

The occurrence of this reaction proves that the base termed trimorphine (and hence also by analogy tricodeine) is actually the *treble* polymeride of morphine—a conclusion hitherto only deduced from the physical properties of the series of polymerides.

Tetramorphine, like tetracodeine, is not acted on by hydrochloric acid.

The so-called "sulphomorphide" of Arppe and of Laurent and Gerhardt, supposed by the latter to be a kind of amide, is found to be nothing but the sulphate of tetramorphine; its formation is accompanied by the production of minute quantities of "apomorphine."

The action of hydrochloric acid on morphine appears to give rise, first, to chlorinated bases derived from non-polymerized morphine—a mixture of substances of compositions ($\bar{M}+HCl$), ($\bar{M}+HCl-H_2O$), and ($\bar{M}+2HCl-2H_2O$) being produced,—and secondly, by the further alteration of these just formed substances, to "apomorphine" and a chlorinated tetra-base ($\bar{M}_4+2HCl$).

The action of hydrochloric acid on codeine is in some respects analogous to, in others different from, that on morphine; the first products formed are derived from non-polymerized codeine, and are $(\bar{C}+HCl)$ and $(\bar{C}+2HCl-2H_2O)$, the latter being the "chlorocodide" of Matthiessen and the author. As "chlorocodide" regenerates ordinary codeine by the action of water in sealed tubes, the production of this base, preceded by that of $(\bar{C}+HCl)$, proves, first, that these substances (and hence by analogy the corresponding morphine derivatives) really belong to the *mono*-series, and, secondly, that monocodeine has the formula $C_{36}H_{42}N_2O_6$, and not (as usually supposed) the half of this, viz. $C_{18}H_{21}NO_3$ (and hence by analogy that monomorphine is $C_{34}H_{38}N_2O_6$, and not $C_{17}H_{19}NO_3$).

In just the same way the first action of hydrobromic acid on codeine is found to give rise to $(\bar{C}+HBr)$, $(\bar{C}+2HBr-2H_2O)$ or "bromocodide" being subsequently produced.

The further action of hydrochloric acid on "chlorocodide" has been shown by Matthiessen and the author to consist in the elimination of methyl as chloride, and the abstraction of the elements of water, forming "apomorphine," the reaction taking place at 140–150° in sealed tubes. When the action is allowed to take place at 100°, however, it follows a slightly different course; methyl chloride is formed and water is eliminated, but the resulting substance is not "apomorphine," but a body which may be regarded as standing intermediate between dimorphine and "apomorphine" (tetrapodimorphine); its physical characters are those of a di-derivative, and it much resembles apomorphine in all respects save composition and physiological action; the recrystallized pure hydrochloride gave numbers leading to the formula $(\bar{M}_2-2H_2O)$, "apomorphine" being $(\bar{M}_2-4H_2O)$; and hence the name *diapodimorphine* is given to this substance. Simultaneously with diapodimorphine, a base isomeric therewith, but belonging to the tetra-series, is produced; this, being indicated by the formula $(\bar{M}_4-4H_2O)$, may be termed *tetrapotetramorphine*.

The alteration in the physiological action (on cats) of the morphine polymerides produced by successive abstraction of the elements of water is well exemplified by the following Table. The last-mentioned base, *octapotetramorphine*, is obtained as the final product of the joint action of concentrated zinc chloride and hydrochloric acid on morphine; its formation is preceded by that of "apomorphine," the base $(\bar{M}+HCl-H_2O)$, and a tetra-base $(\bar{M}_4+HCl-4H_2O)$, the one or the other being formed according to the temperature employed and other circumstances.

Di-Series.

Name of base.	Relation to morphine.	Physiological action.	Observer.
Dimorphine (hypothetical)..	$\bar{M}_2$	?	?
Diapodimorphine	$\bar{M}_2-2H_2O$	Produces profuse salivation but no vomiting (cats).	Dr. J. G. Blackley.
Tetrapodimorphine (apomorphine)	$\bar{M}_2-4H_2O$	Moderately powerful emetic (cats). Very powerful emetic (man).	Drs. Gee and Stocker.

Tetra-Series.

Name of base.	Relation to morphine.	Physiological action.	Observer.
Tetramorphine..............	$\bar{M}_4$	Very powerful emetic (cats).	Dr. Stocker.
Diapotetramorphine........	$\bar{M}_4-2H_2O$	Powerful emetic (cats and dogs).	"
Tetrapotetramorphine	$\bar{M}_4-4H_2O$	Produces profuse salivation but no vomiting (cats).	Dr. Blackley.
Octapotetramorphine	$\bar{M}_4-8H_2O$	Produces neither salivation nor vomiting (cats).	"

It hence appears that the emetic action (on cats) of di-derivatives becomes much increased as the abstraction of the elements of water goes on, whilst the opposite holds in the case of the tetra-derivatives. Isomerides in different series may or may not have the same kind of physiological action; thus diapodimorphine and its isomeride tetrapotetramorphine are not far apart in their effects, whilst tetrapodimorphine and its isomeride octapotetramorphine are very dissimilar—just as morphine, trimorphine, and tetramorphine, or codeine, dicodeine, tricodeine, and tetracodeine are different in physiological action.

The differences in chemical reactions between the four series of polymerides and their derivatives are as well marked as are their physiological properties; thus when either "apomorphine," diapomorphine, or "deoxymorphine" (all of which are di-derivatives) is dissolved in caustic potash solution, a liquid is obtained which rapidly absorbs oxygen from the air: on acidifying this liquid with hydrochloric acid and agitating with ether, a substance is dissolved out which communicates to the ether a magnificent purple tint. This colouring-matter is possessed of the somewhat remarkable property of giving solutions of very different colours and shades with various solvents, the same quantity being dissolved to the same bulk in each case: thus alkalies dissolve it, forming a bright green liquid; water containing ammoniacal salts, a beautiful blue; whilst alcohol, chloroform. bisulphide of carbon, ether, and benzene dissolve it, forming liquids of shades varying from violet-blue to red-purple, but differing in each case. The pure substance is indicated by the formula $C_{40}H_{31}N_2O_7$. It is insoluble in acids, and forms an indigo-blue powder exhibiting traces of crystallization.

Only di-derivatives are capable of giving rise to this colouring-matter; mono-, tri-, and tetra-derivatives of morphine and codeine do not yield a trace of it, provided the substances used are perfectly free from all admixture of di-derivatives.

Again, the action of heat (150°–180°) on the hydrochlorides of monomorphine derivatives causes them to decompose; and on distilling with potash the resulting substance, a mixture of methylamine and *pyridine* is obtained. On subjecting tetramorphine derivatives to the same treatment, *methylamine* only is produced; whilst "apomorphine" (the only di-derivative available in sufficient quantity for the experiment) yields *no volatile base at all* by this treatment.

It would hence seem probable that the relations of the nitrogen to the other elements present are different in the different series of polymerides. Experiments are contemplated with a view to estimating the different amounts of "Intrinsic Chemical Energy" present in equal weights of isomerides in the different series. (*Vide* "Report on Essential Oils.")

The derivatives of morphine and codeine (upwards of forty in number) that have been obtained during the last few years may, with only one or two inconsiderable exceptions, be all regarded as derived from one or other of the polymerides, $\overline{M}$, $\overline{M}_2$, $\overline{M}_3$, $\overline{M}_4$, or $\overline{C}$, $\overline{C}_2$, $\overline{C}_3$, C_4, by addition or subtraction of hydrogen, addition of the elements of hydrochloric (hydrobromic or hydriodic) acid, and elimination of the elements of water; all consequently are expressible by the general formulæ

$$(\overline{C} \pm H_p)_x + mHX - nH_2O,$$

or

$$(\overline{M} \pm H_p)_x + mHX - nH_2O,$$

where

p has values varying from 0 to 8;
$x = 1, 2, 3$, or 4, giving rise to the mono-, di-, tri-, and tetra-series respectively;
m varies from 0 to 4;
n varies from 0 to 12; and
X stands for either Cl, Br, or I.

Thus the base provisionally termed bromotetracodeine may be written

$$\{(\overline{C}-H)_4+2HBr\}, \text{ deoxymorphine as } \{(\overline{M}+H_4)_2-4H_2O\},$$

and so on. Tables giving the composition of these derivatives, formulated and arranged on this principle, are given in the 'Journal of the Chemical Society,' 1873,

p. 228, and the 'Chemical News,' vol. xxvii. p. 287, or in the 'Berichte der Deu Chem. Ges.,' vol. v. p. 1111, and vol. vi. p. 268.

The author again desires to express his thanks to Messrs. Macfarlane and Co., c Edinburgh, for their great kindness and liberality in presenting him with the alka loids necessary for these researches.

GEOLOGY.

Address by John Phillips, *M.A., D.C.L. Oxon., LLD. Cambridge and Dublin, F.R.S., F.G.S.*

More than half the life of an octogenarian separates us from the birthday of the British Association in Yorkshire; and few of those who then helped to inaugurate a new scientific power can be here to-day to estimate the work which it accomplished, and judge of the plans which it proposes to follow in future. Would that we might still have with us the wise leading of Harcourt, and the intrepid advocacy of Sedgwick, names dear to Geology and always to be honoured in Yorkshire!

The natural sciences in general, and Geology in particular, have derived from the British Association some at least of the advantages so boldly claimed at its origin: some impediments have been removed from their path; society looks with approbation on their efforts; their progress is hailed among national triumphs, though achieved for the most part by voluntary labour; and the results of their discoveries are written in the prosperous annals of our native industry.

In most cases scientific truth is established before that practical application is possible which constitutes a commercial revolution and is welcomed with applause by the community. What a change has happened within forty, nay, twenty years, in the ironworks of this country! But long before the foundations of furnaces were laid at Middlesborough, the ferruginous bands in the Yorkshire cliffs had been often explored by geologists, and waited only for the railway to yield millions of tons of ore. The occurrence of good ironstone in the Liassic strata of England is a source of profit as far to the south as Oxfordshire; Northamptonshire yields it in abundance at the base of the Oolites, and Lincolnshire above them; while on the Yorkshire coast, in addition, we have smaller beds in the midst of the Oolites, through nearly the whole range, associated with poor and thin coal.

To determine the extent of the British coal-fields, and the probable duration of the treasures which they yield, and to discover, if possible, other fields quite undreamed of by practical colliers, are problems which geology has been invited to solve; and much progress has been made in these important inquiries by private research and the aid of a public Commission. The questions most interesting to the community—the extent to which known coal-fields spread beneath superior strata, and the situation of other fields having no outcrop to the surface—can often be answered on purely geological grounds, within not very wide limits of probability.

If, for example, we ask how far to the eastward the known coal-strata may extend under the Vale of York, a reasonable answer is furnished by Mr. Hull and the Government Commission. The whole great coal deposit, extending from Bradford to Nottingham, passes under the Magnesian Limestone, and may be found for at least a few miles in breadth within attainable depths. It passes under a part of the Vale of York, probably south of the city. But before attempting to give a practical value to this opinion, it may be well to remember that, fully tried, the experiment would be too costly for individual enterprise, while if successful it would benefit more than a county, and that not only a large outlay must be provided for it, but arrangements made for persevering through several years in the face of many difficulties and perhaps eventual disappointment. Still, sooner or later, the trial must be made; and geology must direct the operation.

Considerations of this kind invest with more than momentary interest the great

undertaking to which Mr. Godwin-Austen called attention in his address to the Geological Section at Brighton. Not to dig gypsum, not to open a new supply of salt, not to discover coal in Sussex, but to find out what is below the Wealden, and thus contribute to solve a great practical problem for London and all the south of England, have geologists undertaken the deep boring near Hastings. What is below the Wealden? Do the oolitic rocks continue beneath it with their usual characters and thickness? or do they suffer that remarkable diminution which is observed in their eastward declination through the midland counties? Do they occur at all there? may they lie only in separate patches amidst older rocks? may these older rocks, continued from Belgium, appear at once or at no great depth below the Wealden, and bring with them, if not coal, some sure knowledge of the way in which the great subterranean anticlinal passes from the Rhineland through Belgium to Somerset, South Wales, and Ireland? Such an experiment must not be allowed to come to a premature end.

Turning, however, from these topics, which involve industrial interests, to other lines of geological research, we remark how firmly since 1831 the great facts of rock-stratification, succession of life, earth-movement, and changes of oceanic areas have been established and reduced to laws—laws, indeed, of phenomena at present, but gradually acquiring the character of laws of causation.

Among the important discoveries by which our knowledge of the earth's structure and history has been greatly enlarged within forty years, place must be given to the results of the labours of Sedgwick and Murchison, who established the Cambro-Silurian systems, and thus penetrated into ancient time-relics very far toward the shadowy limit of palæontological research. Stimulated by this success, the early strata of the globe have been explored with unremitting industry in every corner of the earth; and thus the classification and the nomenclature which were suggested in Wales and Cumberland are found to be applicable in Russia and India, America and Australia, so as to serve as a basis for the general scale of geological time, founded on organic remains of the successive ages.

This great principle, the gift of William Smith, is also employed with success in a fuller study of the deposits which stand among the latest in our history and involve a vast variety of phenomena, touching a long succession of life on the land, changes of depth in the sea, and alterations of climate. Among these evidences of physical revolution, which, if modern as geological events, are very ancient if estimated in centuries, the earliest monuments of man find place—not buildings, not inhabited caves or dwellings in dry earth-pits, not pottery or fabricated metal, but mere stones shaped in rude fashion to constitute apparently the one tool and one weapon with which, according to Prestwich, and Evans, and Lubbock, the poor inhabitant of northern climes had to sustain and defend his life.

Nothing in my day has had such a decided influence on the public mind in favour of geological research, nothing has so clearly brought out the purpose and scope of our science, as these two great lines of inquiry, one directed to the beginning, the other to the end of the accessible scale of earthly time; for thus has it been made clear that our purpose can be nothing less than to discover the history of the land, sea, and air, and the long sequence of life, and to marshal the results in a settled chronology—not, indeed, a scale of years to be measured by the rotations or revolutions of planets, but a series of ages slowly succeeding one another through an immensity of time.

There is no question of the truth of this history. The facts observed are found in variable combinations from time to time, and the interpretations of these facts are modified in different directions; but the facts are all natural phenomena, and the interpretations are all derived from real laws of those phenomena—some certified by mathematical and mechanical research, others based on chemical discovery, others due to the scalpel of the anatomist, or the microscopic scrutiny of the botanist. The grandest of early geological phenomena have their representatives, however feeble, in the changes which are now happening around us; the forms of ancient life most surprising by their magnitude or singular adaptations can be explained by analogous though often rare and abnormal productions of to-day. Biology is the contemporary index of Palæontology, just as the events of the nineteenth century furnish explanations of the course of human history in the older times.

To forget, in referring to this subject, the name of our great and veteran leader, Sir Charles Lyell, would be difficult for any who have profited by the perusal of his masterly works, is impossible for those who, like me, have been witnesses of that life-long zeal and energy which carried him to explore distant regions and make friends for English Geology in every quarter of the globe.

Keeping our attention on Pleistocene Geology, we may remark that the famous cavern of Kirkdale, with the equally celebrated rock den of bears and hyænas at Torquay, receive no small help toward clearing up the history of mammalia in Britain from the explorations now going on in the limestone cliffs not far from this place of meeting. In Kirkdale Cave no trace of human art appeared; Kent's Hole has given proofs of the presence of man from the earliest period characterized by the remains of the great bear; and both there and in the Victoria Cave near Settle, at much later periods, domestic occupation is fully established.

It will be readily conceded that for gathering good information regarding the aborigines of our land the British Association has wisely appropriated some portion of its funds; probably we shall agree in thinking that the additional data which may be expected are worthy of further expenditure and the employment of valuable labour. And this leads me to remark how real is the obligation of this Association to some of its members who have directed these researches, and how large a debt of gratitude is due to one in particular, who, not content with turning every day his intelligent eyes on the remarkable phenomena disclosed by excavation in the Torquay caverns, has with his own hands cleared and washed thousands of bones and teeth, studied, labelled, and arranged them, and year by year has delighted this Section with careful narratives of what he and Mr. Vivian, following the steps of MacEnery, have surely observed and recorded. Labour of this kind the Association cannot purchase; nor would the generous spirit of my friend consent to such a treaty. I may, however, use the privilege of my temporary office, and suggest to you to consider whether the time is not come for the friends of the Association, and especially the members of this Section, to unite in a general effort, and present to Mr. Pengelly a substantial proof that they highly appreciate his disinterested labours in their service, and the ample store of new knowledge which he has had so large a share in producing.

During the long course of geological time the climates of the earth have changed. In many regions evidence of such change is furnished by the forms of contemporary life. Warm climates have had their influence on the land, and favoured the growth of abundant vegetations as far north as within the arctic circle; the sea has nourished reef-making corals in Northern Europe during Palæozoic and Mesozoic ages; crocodiles and turtles were swimming round the coasts of Britain, among islands clothed with *Zamiæ* and haunted by marsupial quadrupeds. How have we lost this primæval warmth? Does the earth contribute less heat from its interior stores? does the atmosphere obstruct more of the solar rays or permit more free radiation from the land and sea? has the sun lost through immensity of time a sensible portion of his beneficent influence? or, finally, is it only a question of the elevation of mountains, the course of oceanic currents, and the distribution of land and sea?

The problems thus suggested are not of easy solution, though in each branch of the subject some real progress is made. The globe is slowly changing its dimensions by cooling; thus inequalities and movements of magnitude have arisen and are still in progress on its surface: the effect of internal pressure, when not resulting in mass-movement, is expressed in the molecular action of heat which Mallet applies to the theory of volcanoes. The sun has no recuperative auxiliary known to Thomson for replacing his decaying radiation; the earth, under his influence, as was shown by Herschel and Adhemar, is subject to periods of greater and less warmth, alternately in the two hemispheres and generally over the whole surface; and finally, as Hopkins has shown, by change of local physical conditions the climate of northern zones might be greatly cooled in some regions and greatly warmed in others.

One is almost frozen to silence in presence of the vast sheets of ice which some of my friends (followers of Agassiz) believe themselves to have traced over the mountains and vales of a great part of the United Kingdom, as well as over the kindred

regions of Scandinavia. One shudders at the thought of the innumerable icebergs with their loads of rock, which floated in the once deeper North Sea, and above the hills of the three Ridings of Yorkshire, and lifted countless blocks of Silurian stone from lower levels, to rest on the precipitous limestones round the sources of the Ribble.

Those who, with Professor Ramsay, adopt the glacial hypothesis in its full extent, and are familiar with the descent of ice in Alpine valleys where it grinds and polishes the hardest rocks and winds like a slow river round projecting cliffs, are easily conducted to the further thought that such valleys have been excavated by such ice-rubbers, and that even great lakes on the course of the rivers have been dug out by ancient glaciers which once extended far beyond their actual limits. That they did so extend is in several instances well ascertained and proved; that they did in the manner suggested plough out the valleys and lakes is a proposition which cannot be accepted until we possess more knowledge than has yet been attained regarding the resistance offered by ice to a crushing force, its tensile strength, the measure of its resistance to shearing, and other data required for a just estimate of the problem. At present it would appear that, under a column of its own substance 1000 ft. high, ice would not retain its solidity; if so, it could not propagate a greater pressure in any direction. This question of the excavating effect of glaciers is distinctly a mechanical problem, requiring a knowledge of certain data; and till these are supplied, calculations and conjectures are equally vain.

A distinguishing feature of modern geology is the great development of the doctrine that the earth contains in its burial-vaults, in chronological order, forms of life characteristic of the several successive periods when stratified rocks were deposited in the sea. This idea has been so thoroughly worked upon in all countries, that we are warranted to believe in something like one universal order of appearance in time, not only of large groups but even of many genera and species. The Trilobitic ages, the Ammonitic, Megalosaurian, and Palæotherian periods are familiar to every geologist. What closed the career of the several races of plants and animals on the land and in the sea, is a question easily answered for particular parts of the earth's surface by reference to "physical change;" for this is a main cause of the presence or absence, and in general of the unequal distribution of life. But what brought the succession of different races in something like a constant order, not in one tract only, but, one may say, generally in oceanic areas over a large portion of the globe?

Life unfolds itself, in every living thing, from an obscure, often undistinguishable cell germ, in which resides a potential of both physical and organic change—a change which, whether continual or interrupted, gradual or critical, culminates in the production of similar germs, capable under favourable conditions of assuming the energy of life.

How true to their prototypes are all the forms with which we are familiar, how correctly they follow the family pattern for centuries, and even thousands of years, is known to all students of ancient art and explorers of ancient catacombs. But much more than this is known. Very small differences separate the elephant of India from the mammoth of Yorkshire, the *Waldheimia* of the Australian shore from the *Terebratula* of the Cotswold oolite, the dragonfly of our rivers from the *Libellula* of the Lias, and even the *Rhynchonellæ* and *Lingulæ* of the modern sea from the old species which swarm in the Palæozoic rocks.

But concurrently with this apparent perpetuity of similar forms and ways of life, another general idea comes into notice. No two plants are more than alike; no two men have more than the family resemblance; the offspring is not in all respects an exact copy of the parent. A general reference to some earlier type, accompanied by special diversity in every case ("descent with modification"), is recognized in the case of every living being.

Similitude, not identity, is the effect of natural agencies in the continuation of life-forms, the small differences from identity being due to limited physical conditions, in harmony with the general law that organic structures are adapted to the exigencies of being. Moreover the structures are adaptable to new conditions; if the conditions change, the structures change also, but not suddenly; the plant or animal may survive in presence of slowly altered circumstances, but must perish

under critical inversions. These adaptations, so necessary to the preservation of a race, are they restricted within narrow limits? or is it possible that in the course of long-enduring time, step by step and grain by grain, one form of life can be changed and has been changed to another, and adapted to fulfil quite different functions? Is it thus that the innumerable forms of plants and animals have been "developed" in the course of ages upon ages from a few original types?

This question of development might be safely left to the prudent researches of Physiology and Anatomy, were it not the case that Palæontology furnishes a vast range of evidence on the real succession in time of organic structures, which on the whole indicate more and more variety and adaptation, and in certain aspects a growing advance in the energies of life. Thus at first only invertebrate animals appear in the catalogues of the inhabitants of the sea; then fishes are added, and reptiles and the higher vertebrata succeed; man comes at last, to contemplate and in some degree to govern the whole.

The various hypothetical threads by which many good naturalists hoped to unite the countless facts of biological change into an harmonious system have culminated in Darwinism, which takes for its basis the facts already stated, and proposes to explain the analogies of organic structures by reference to a common origin, and their differences to small, mostly congenital, modifications which are integrated in particular directions by external physical conditions, involving a "struggle for existence." Geology is interested in the question of development, and in the particular exposition of it by the great naturalist whose name it bears, because it alone possesses the history of the development *in time*, and it is to inconceivably long periods of time, and to the accumulated effect of small but almost infinitely numerous changes in certain directions, that the full effect of the transformations is attributed.

For us, therefore, at present it is to collect with fidelity the evidence which our researches must certainly yield, to trace the relation of forms to time generally and physical conditions locally, to determine the life-periods of species, genera, and families in different regions, to consider the cases of temporary interruption and occasional recurrence of races, and how far by uniting the results obtained in different regions the alleged "imperfection of the geological record" can be remedied.

The share which the British Association has taken in this great work of actually reconstructing the broken forms of ancient life, of repeopling the old land and older sea, of mentally reviving, one may almost say, the long-forgotten past, is considerable, and might with advantage be increased. We ask, and wisely, from time to time, for the combined labour of naturalists and geologists in the preparation of reports on particular classes or families of fossil plants and animals, their true structure and affinities, and their distribution in geological time and geographical space. Some examples of this useful work will, I hope, be presented to this Meeting. Thus have we obtained the aid of Agassiz and Owen, and have welcomed the labours of Forbes, and Morris and Lycett, and Huxley, of Dawkins and Egerton, of Davidson, Duncan, and Wright, of Williamson and Carruthers and Woodward, and many other eminent persons, whose valuable results have for the most part appeared in other volumes than our own.

Among these volumes let me in a special manner recall to your attention the priceless gift to Geology which is annually offered by the Palæontographical Society, a gift which might become even richer than it is, if the literary and scientific part of our community were fortunate enough to know what a perpetual treasure they might possess in return for a small annual tribute. The excellent example set and the good work recorded in the Memoirs of the Society referred to have not been without influence on foreign men of science. We shall soon have such Memoirs from France and Italy, Switzerland and Germany, America and Australia; and I trust the effect of such generous rivalry will be to maintain and increase the spirit of learned research and of original observation which it is our privilege and our duty to foster, to stimulate, and to combine.

On all the matters, indeed, which have now been brought to your thoughts the one duty of geologists is to collect more and more accurate information; the one fault to be avoided is the supposition that our work is in any department complete. We should speak modestly of what has been done; for we have completed nothing,

except the extinction of a crowd of errors, and the discovery of right methods of proceeding toward the acquisition of truth. We may speak hopefully of what is to be accomplished; for the right road is before us. We have taken some steps along it; others will go beyond us and stand on higher levels. But it will be long before any one can reach the height from which he may be able to survey the whole field of research and collect the results of ages of labour,

.... primaque ab origine mundi
Ad sua perpetuum deducere tempora carmen.

Additional Remains of Pleistocene Mammals in Yorkshire.
By the Rev. J. F. Blake.

The bones referred to were discovered in the recent working of an old marl-pit at Bielbecks near North Cliff, whence mammalian remains have been previously obtained. The first discovery was recorded by the Rev. W. V. Vernon Harcourt in the 'Philosophical Magazine' for 1829. More remains were deposited in the York Museum when the excavations were renewed about twenty years later; and this last summer many more have been exhumed. These latter were exhibited. The complete list of the hitherto discovered bones is as follows:—(1) mentioned by Vernon Harcourt; (2) in York Museum; (3) recently found, and now also deposited in York Museum.

Mammoth. 3 teeth, lower jaw (1) (3); 3 teeth, upper jaw (3); 1 symphysis of lower jaw (3); 2 tusk ends, and portions of tusk (3); atlas (3); axis (2); pelvic (2); cervical vertebra (3); head of femur (3); broken ditto (1)(epiphyses); 2 shafts of femur (3); 1 distal end of femur (3); 1 tibia (?) (3); 2 distal ends, ditto (3) (a pair); 2 astragali (3) (2); 1 os semilunare (2); 1 cuboid? (3); 1 third metacarpal (3).

Elephas antiquus. 1 molar, 1 ditto unused.

Rhinoceros. 2 teeth and jaw (1); 3 tibia (1) (3); 1 rib (1); vert. (2); distal end of femur (?) (2).

Bos. 1 occipital bone (1); 2 horns (1); 2 vertebræ (1); 1 left radius (1); 1 ulna (3); 1 distal end of femur (3); 3 iliac bones (3); 1 right tibia (3); 1 metacarpal (3); 1 metatarsal (1); 1 astragalus (1); 2 calcanea (1) (3); 3 phalangeal bones (3). (Some of these may be Bison.)

Stag. Small portions of horn (1) (3).

Red Deer. Metacarpal (3).

Horse. 1 distal end of femur (3); metatarsus, phalanges, and hoof *in situ* (2); right scapula (2); 1 radius and ulna (joined) (2); ? vertebræ and (epiphyses); 1 coronary (1); 1 metacarpal (1).

Bear. 1 tibia (3).

Lion? (*Felis*). Upper jaw with two molars (1); lower jaw, several molars, 6-inch long symphysis (1); 1 head of femur (1); 1 radius (1); 3 metacarpals (1); 1 rib (1).

Wolf. Right lower jaw (2); ulna (2); radius (2); humerus (2).

Unknown. Ruminant? metacarpal; shaft of long bone; ditto of metacarpals, &c.

Duck. Ulna (2); clavicle (2); tibia (2).

The deposit in which these occur is covered with a bed of flint gravel; but no human weapons have been found in it; all the associated shells are recent, and belong to river or marsh species. The bones were mostly found in one spot, but some of the mammoth at a little distance away. It is noteworthy that no Hippopotamus bones have yet been found. The age is probably later Pleistocene, though there is little to indicate it in the fossils; but it is in all probability postglacial, being a tranquil deposit; and there are glacial beds at nearly the same level in the neighbourhood, so that if it had been preglacial it would probably have been carried away.

On some Evidence of Glacial Action in Tropical India in Palæozoic (or the oldest Mesozoic) times. By W. T. BLANFORD, *F.G.S., C.M.Z.S.*

The author in the year 1856, when describing some rocks in Orissa, suggested that a very peculiar association of large boulders with fine shales might have been due to the transport of the boulders by ground-ice. A similar deposit has been traced throughout a very large area in Bengal and the Central Provinces in India, and is always characteristic of the base of the Talchir group, the lowest member of the great series of plant-bearing rocks, for which the name of Gondwana series has recently been suggested. Quite recently Dr. Oldham, the Superintendent of the Geological Survey of India, has found scored and striated blocks in this Talchir boulder bed, the surface upon which the bed rests being also polished and grooved.

The theory (of boulders, sand, and clay slipping downwards on low slopes during the gradual elevation of land above the sea) put forward by Mr. Mallet to account for similar phenomena, and which was considered by General Portlock in 1857 to explain the peculiar association of large boulders and fine silt, does not appear satisfactory; for, amongst other difficulties, it leaves the fact of many of the boulders having come from a distance entirely unexplained. Mr. Blanford, whilst aware of the apparent incongruity involved in invoking the aid of ice to explain phenomena occurring in a tropical country, can suggest no other explanation of the facts.

The exact age of the Talchir is still doubtful; but there can be but little doubt of their being pre-Triassic.

On Archædiscus Karreri, *a New Type of Carboniferous Foraminifera.* By HENRY B. BRADY, *F.L.S., F.G.S.*

This paper contained a detailed description of certain minute unsymmetrical lenticular fossils $\frac{1}{25}$ of an inch in diameter and $\frac{1}{50}$ of an inch in thickness, from the "Main Limestone" of the Lower Carboniferous Limestone series of Lanarkshire, and the Mountain Limestone of Great Orme's Head, Caernarvonshire.

They were shown to be Foraminifera closely allied to *Nummulina*, and differing primarily from that genus in being composed of a non-septate tube coiled on itself in varying directions, and thickened on the exterior (especially near the centre of the disk) by the deposit of shell-substance, instead of the symmetrical, regularly coiled spiral line of chambers characteristic of the more highly developed type. The particulars entered into concerning the minute structure of the type would be unintelligible without the figures by which the paper was illustrated *.

The generic term *Archædiscus* was proposed for the new type.

On such of the Industries of Bradford as relate to its Geological Position. By JOHN BRIGG.

After briefly pointing out the geological position of Bradford, the author proceeded to notice the excellent quality of the building-materials of the district, drawing special attention to the rough sandstone rocks which are technically termed Grits. The extreme durability of this stone was pointed out, also the appropriateness of its use for engine-beds, floors of dock-gates, and the basements of large buildings. Its power of withstanding the injurious effects of constant exposure to water was also mentioned. The laminated rocks which underlie some parts of the town of Bradford were next dwelt upon, and their suitability for roofing-slates, flags, and paving-stones, as well as for ordinary building stones, was described.

The New Town Hall, and particularly the Statues of the Kings, which form its chief architectural ornament, were instanced as examples of the finest sandstone that can be used for public buildings. The author then spoke of the Calliard or Gannister beds in the Grit and Coal series, pointing out their position as being the

* The paper is published in full in the 'Ann. & Mag. Nat. Hist.' for October 1873.

same, and containing the same fossils as the fireclay which is the usual seat of the coal. The use of Calliard for producing the fine sand used in the moulding of iron and brass was explained, as also the process by which the stone is reduced.

The manufacture of firebricks, sanitary tubes, and domestic pottery from the fireclay of the Halifax coal-seam was explained, as also the process by which sulphate of iron is made from the pyrites contained in the same seam. The author proceeded at some length to describe the position and quality of the irregular seams of coal which are found beneath the Rough Rock, and also pointed out the peculiarities of the two seams of coal called the Halifax Hard and Soft beds, which are usually classed as the lowest of the true Coal-measures. The line of their outcrop was also pointed out.

The paper also contained a short description of the ancient bloomeries in the district, and concluded with a notice of the seams of iron and coal found at Bowling and Low Moor.

On the Discovery of a Species of Starfish in Devonian Beds of South Devon. By A. Champernowne.

The only record hitherto, so far as I know, of the occurrence of Starfish in British Devonian rocks, is that given by Mr. Etheridge in his list of Devonian Fossils (Q. J. Geol. Soc. vol. xxiii. p. 619), viz. *Protaster*, sp., and *Palæaster*, sp., from the Pilton beds of North Devon; therefore the discovery of a species in South-Devon rocks may not be without interest.

The locality which yielded the few specimens in question is a small quarry at Inglebourne House near Harbertonford (about three miles S.S.W. of Totnes), in slates with one or two thin gritty layers, on one of which, forming part of the floor of the quarry, were the impressions.

The dip is about S.E. (20° east of south magnetic) at 15°, crossed by cleavage at a higher angle towards the south.

Viewed in connexion with the Harbertonford limestone, and the slate-quarry at Roster Bridge, the beds would appear to belong to the *Upper* South-Devon series.

In the old quarries at Harbertonford the limestone and shale dip north at 10°, the angle heightening to 25° close to the Vicarage; and in the adjoining cutting of the Kingsbridge road, the slates, rising to the south with undulations, are apparently below the limestone. This would seem to produce the line of the limestone to the north of the Harber at Woodcourt, and probably to the north of Roster-Bridge slate-quarry (where Spirifers and other fossils are numerous), and hence to trough some slates in the neighbourhood of Inglebourne which contain the Starfish *. At Roster-Bridge quarry the cleavage is the predominant feature, the bedding being at variance with the S.S.E. dip shown on the map north of Dolling, half a mile to the west.

[The impression of the body-plates is unfortunately wanting in the specimens of Starfish which were intrusted to my friend Mr. Lee; but I venture to hope they may be described by some more experienced palæontologist than myself, the object of this paper being merely to record the fact of their occurrence, and to describe the locality.]

Note by Henry Woodward, *F.R.S., on* A. Champernowne's *Paper.*

Two Devonian Starfishes have been noted† by Mr. Etheridge, F.R.S., in the Devonian of North Devon, which he refers to the genera *Protaster*, sp., and *Palæaster*, sp., from Middle and Upper Devonian of Pilton ‡.

Prof. Ferd. Roemer records four genera (namely, *Aspidosoma Tischbeinianum*,

* I revisited the spot in company with Mr. J. E. Lee and Mr. Paige-Browne, of Inglebourne House, and owner of the quarry; and this was the view taken by the latter, who considered the roofing-slates of Roster-Bridge quarry deeper in the series than the slates around his house, and the last nearly on the horizon of the limestone of Harbertonford. Our search for Starfish, however, was fruitless.

† See 'Quart. Journ. Geol. Soc.' 1867, vol. xxiii. pp. 619, 670.

‡ Mr. E. Etheridge informs me that these Starfishes are both of *Upper* Devonian age, and that the reference to Middle Devonian, on p. 670, *op. cit.*, is a typographical error.

Asterias asperula, A. spinosissima, Helianthaster rhenanus) from the Devonian of Bundenbach bei Birkenfeld *.

Prof. Morris informs me he has no knowledge of any other species from these beds.

Fifteen genera and fifty species of Starfishes have been recorded from the Silurian. Of these various forms the *Helianthaster rhenanus*, Birkenfeld Devonian, and the *Lepidaster Grayi*, from the Wenlock Limestone, Dudley, offer the nearest analogy with the fossil Starfish found by Mr. Champernowne in South Devon. All three forms belong to the family of the *Solasteriæ*, or many-rayed sun stars.

Bearing in mind that the Asteriadæ were preceded in point of time, as also in point of development by the Crinoidea, the discovery of so many additional forms of Palæozoic Starfishes, shows us how far we are from the beginning of this group in time.

Only lately Dr. Henry Hicks, F.G.S., has discovered a new Crinoid in the Lower Cambrian Rocks of St. David's, carrying back the class to an extremely distant point in palæozoic time.

On the Geology of part of Craven. *By* J. R. Dakyns, *M.A.*

The type of millstone-grit prevalent in Derbyshire undergoes considerable changes north of Bradfield; the second grit becomes merely a basement-bed to the Rough Rock; the third grit loses its massive character; and other beds of sandstone begin to show themselves in the shales overlying the Kinder-Scout grit.

In the valleys of the Colne and Calder there are four separate sandstones between the Rough Rock and the Kinder-Scout grit.

In the basin of the Aire the series consists in descending order:—first, of the Rough Rock, which maintains its usual marked character throughout; secondly, of a very variable basement-bed to the last, consisting, when well developed, of valuable flagstones. These are extensively quarried at Nab, above Oxenhope Moor, and also in an outlier at the Penistone quarries near Haworth. Below this bed comes a series of variable sandstones and shales. There may be in places as many as fifteen or sixteen distinct sandstones between the basement of the Rough Rock and the Kinder-Scout grit.

But this set of beds may conveniently be divided into two by means of a conspicuous grit, which is continuous with the third grit of Lancashire. This grit forms the bold escarpment of Hallan hill and Earl crag. We may conveniently speak of it as the middle grit. It generally has three grits between it and the base of the Rough Rock; and these four beds are presumably the four grits of the Calder and Colne valleys.

The general run of the rocks in the basin of the Aire is as follows:—The Rough Rock runs in a nearly unbroken manner from the latitude of Penistone, and enters the basin of the Aire above Oxenhope Moor: its basement flags form the Nab escarpment. A large fault, crossing Thornton Moor in W.N.W. direction, throws down the Coal-measures of Denholme on the north, from beneath which the Rough Rock rises to form Black and Brow moors. Another W.N.W. fault throws the beds up again near Cullingworth, so that Harden Moor, between Bingley and Keighley, consists of an outlier of Rough Rock, while various members of the third grit series form the flanks of the hill. West of the river Worth a dip slope of Rough Rock forms Keighley Moor; but at Exley Head another W.N.W. fault throws up the beds to the north, so that an outlier of Rough Rock forms the hill on which is situated Keighley Tarn. Going N.W. from the tarn one passes successively over the various members of the third grit series. The middle grit, clearly marked by its massive character, runs down to the valley south of Hawkcliff cottage; it ascends on the north side of the Aire, somewhat broken by faults, and forms Brunthwaite and White crags, and the escarpment of Addingham Moor. It is this rock which forms the Brimham rocks near Pateley Bridge. Below the

* Palæontographica, Bd. ix. (1862–64) pp. 143–152, pls. 23–29.

middle grit there is no conspicuous rock south of the Aire; but north of that river several beds of sandstone appear, one of which becomes important further north as the hard siliceous "homestone" grit with gannister, which forms the top of Great Whernside. The Kinder-Scout grit is brought in south of the Aire by a W.N.W. fault containing galena. North of the Aire it rises up regularly from beneath the overlying beds at Kildwick. Near Cononley the beds are repeated by a N.E. fault throwing down on the N.W. The Kinder-Scout grit is immediately underlain by a variable set of sandstones with shale partings, usually called Yoredale grit. Below these are found, at Skipton, shales and limestones. The strike of the beds hitherto described is N.E. and S.W.; but about the latitude of Skipton the strike changes to E. and W., with a dip of 20° to the south along Skipton Moor. The whole country, in fact, between the latitudes of Skipton and Grassington has been much disturbed and thrown into a series of east and west rolls. Thus a strong anticlinal ranges up the Skibeden valley from Skipton to Bolton Abbey. A mass of mountain-limestone, forming Haw Park, is thus brought up in the Skibeden valley between two ranges of millstone-grit hills, viz. the Skipton Moor and Embsay Moor. The mountain-limestone here is a dark thin-bedded limestone. It is much quarried for road material at Haw Bank and at Thornton. The beds are much contorted along the south side of Skibeden. Two limestones are seen on the north side above the mountain-limestone. On the south side of the Skibeden anticlinal the Kinder-Scout grit strikes E. and W. along Skipton and Draughton moors, and descends to the Wharfe north of Addingham. The southerly dip carries it up the slope of Langbar Moor, its base running below Beamsley Beacon; it then plunges down northward to Kex beck, where the beds bend up again and rise northward to Hazlewood Moor and Bolton Park: here the beds bend over northward and recross the Wharfe below Laund House. South of this, as far as Bolton Abbey, limestones and shales of the Yoredale series are seen along the river. These beds are cut off opposite Bolton Abbey by a N.E. fault bringing in the upper beds. The Yoredale grits run along the slopes of Skipton Moor to Fairfield Hall, and east of the Wharfe are found about Beamsley and Storriths. They have not been everywhere identified north of Skibeden. A set of bold crags marks the escarpment of the Kinder-Scout grit along Halton and Embsay moors, Rilstone, Burnsall, and Thorpe fells. Beneath the western escarpment of the Kinder-Scout grit the Yoredale grit is found, forming at intervals promontories on the side of the fell. It has not been traced further east than the northern extremity of Burnsall Fell. The Kinder-Scout grits lie in the shape of a synclinal trough dipping east, and thus occupy the whole extent of Burnsall Fell and Barden and Embsay moors. On the east of the Wharfe these grits rise up in a sort of broken dome, with a quaquaversal dip to form the summit of Barden Fell marked by the crags of Simon's Seat, near which some pot-holes indicate the presence of limestone at no great depth. In Howgill and in Fell Plantation the beds are dipping steeply to the N.W. into the valley; but north of Skyreholme beck they dip steeply to the S.E., underlain by shales, from beneath which massive white scar limestone rises regularly with a similar strike, as far as the Ordnance Station, 1350 feet above sea-level, where the beds are cut off by the Craven fault. The position of this fault is also shown by the abrupt termination of Fancarl crags, and by disturbance of beds at Thruskell Well, Hebden, and by disturbed beds on the banks of Wharfe near Lyth House; thence the fault runs by Skirethorns to the cliffs which mark the line of the fault from Malham to Settle. East of the river Dibb we have north of the Craven fault massive white limestone dipping north at 19°, closely overlain by the grits of Grimwith Fell, the upper part of the limestone containing a band of mixed shales, limestones, and calcareous sandstones. Between the Dibb and Grassington the millstone-grits seem to be separated from the limestone by a great thickness of shales, with but poor limestone bands. At Grassington the limestones swell out; and, with the exception of a band of hard sandstones (the Dirt-Pot grits), there is solid limestone from the grits of Grassington Moor to the Wharfe. Northwards the limestone gradually breaks up, and finally takes on the Yoredale type.

Observation on the Rate at which Stalagmite is being accumulated in the Ingleborough Cave.* By W. Boyd Dawkins, *M.A., F.R.S., F.G.S.*

The only attempt to measure with accuracy the rate of the accumulation of stalagmite in caverns in this country, is that made by Mr. James Farrer in the Ingleborough Cave, in the years 1839 and 1845, and published by Professor Phillips in 'The Rivers, Mountains, and Sea Coast of Yorkshire' (second edition, 1855, pp. 34, 35). The stalagmite, called "the Jockey Cap," rises from a crystalline pavement to a height of about $2\frac{1}{2}$ feet, and is the result of the deposit of carbonate of lime.

For the sake of ensuring accuracy, three holes were bored at the base of the stalagmite, and three gauges of brass wire (gilt) inserted, to mark the points where the measurements were taken.

The following is an abstract of the Table of measurements:—

	March 13, 1873.	1839.	Oct. 30, 1845.	Increase since 1845.	Rate of increase per annum.
	in.	in.	in.	in.	in.
Roof to apex of Jockey Cap	87	......	95·25	8·25	·2946
Roof to tip of stalactite	......	......	10		
Stalactite to apex of Jockey Cap	......	......	85·25		

The only possible ground of error is the erosion of the general surface of the solid limestone, of which the roof is composed, by carbonic acid, since the year 1845; and this is so small as to be practically inappreciable. There is therefore evidence that the "Jockey Cap" is growing at the rate of ·2946 of an inch per annum, and that, if the present rate of growth be continued, it will finally arrive at the roof in about 295 years. This comparatively short lapse of time will probably be diminished by the growth of a pendent stalactite above, that is now being formed in place of that which measured 10 inches in 1845, and has since been accidentally destroyed. It is very possible that the "Jockey Cap" may be the result, not of the continuous, but of the intermittent drip of water containing a variable quantity of carbonate of lime, and, therefore, that the present rate of growth is not a measure of its past or future condition. All the stalagmites and stalactites in the Ingleborough Cave, at this rate, may not be older than the time of Edward III. From this it follows that the thickness of layers of stalagmite cannot be used as an argument in support of the remote age of the strata which they cover in the caverns, such as Kent's Hole and Bruniquel. At the rate of a quarter of an inch per annum, 20 feet of stalagmite might be formed in 1000 years.

Note on the Stump-Cross Caverns at Greenhow near Pately Bridge. By J. W. Ellis.

These caverns were discovered in 1860 by miners who were searching for lead, and who cut into them at a depth of 9 fathoms from the surface. The paper gave a description of the caverns, which are chiefly remarkable for the great beauty of the stalactites which they contain.

The Round Boulder Hills of Craven. By W. Gomersall.

The author described some hills of Boulder-clay which lie between the rivers Aire and Ribble; their elevation, above the base on which they stand, varies from 100 to 300 feet. The highest hills are to the north and west of the group, whilst they gradually diminish in size to the south and east. The author supposed the Boulder-clay to have been brought by icebergs, and deposited in what was then a bay of the sea.

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* See Proc. of Manchester Lit. and Phil. Soc. Feb. 1873.

On the Probability of finding Coal in the Eastern Counties. By the Rev. JOHN GUNN.

This paper was supplementary to one read at the Brighton Meeting upon the same subject, in which the author dwelt principally on the evidence of repeated successive elevations and depressions in the Anglo-Belgian basin since the Carboniferous epoch; and he thence inferred that similar depressions may be expected to have occurred during it, when the coal may have been deposited in troughs and hollows, and have escaped subsequent denudations. The author dwelt upon the westerly upheaval of the beds which has brought the whole of the Cretaceous rocks to the surface and has exposed the Kimmeridge clay near Lynn and Hunstanton; he therefore thought that the Coal-measures, if present at all, of which he felt very sanguine, would be reached at a less depth there than elsewhere.

The author would not propose to press the boring in the west of Norfolk in preference to that proposed by Mr. Godwin-Austen in the south of Essex; but when the latter is completed, he will have no doubt of raising the necessary funds if the site which he proposes be approved by geologists.

On the Occurrence of Faults in the Permian Rocks of the lower portion of the Vale of the Eden, Cumberland. By Professor HARKNESS, *F.R.S., F.G.S.*

The Permian rocks occupying the vale of the Eden have their southern limit at Kirkby Stephen in Westmoreland; thence they extend, over the more level country through which the river flows, to near Carlisle.

The strike of these Permian rocks from Kirkby Stephen to near Armathwaite is nearly N.N.W. and S.S.E. They consist of:—first and lowest, light red-coloured sandstones very false-bedded (Penrith sandstones); second, red clays having gypsum frequently associated with them—and in one instance, near Hilton in Westmoreland, light drab shales with plant-remains (marl slate), and a limestone at their base; the third member of the series is composed of fine-grained dark red sandstones, very regularly bedded with red clays intercalated in them.

Had these Permian rocks followed their ordinary strike along the whole of the vale of the Eden, the gypsiferous red clays would have crossed the river a short distance above Armathwaite Bridge. They do not, however, occur in the bed of the river near this spot, although rocks are here abundantly exposed—the last spot where they have been recognized with their ordinary strike being at Cross House near Ruckcroft, about three miles south of Armathwaite.

The area where they might have been expected to occur in the neighbourhood of Armathwaite, is occupied by the underlying Penrith sandstones; and these spread themselves eastwards into the parish of Ainstable, into a district in which the Upper Permian rocks (the Corby sandstones) would have been seen had the range of these rocks been such as is exhibited in the vale of the Eden south of Armathwaite.

The great development of the Penrith sandstones at Armathwaite and Ainstable, and the absence here of the gypsiferous clays and overlying Corby sandstones, the author regards as resulting from a fault having a nearly S.W. and N.E. course, with an upthrow on the N.W. side.

Still further down the Eden there are seen, in consequence of a cutting recently made at Eden Brows on the Carlisle and Settle Railway, exposing the rocks, strata of purplish white sandstones having interbedded grey shales. These sandstones and shales appertain to the Carboniferous formation; and their occurrence here appears to result from another fault, which has also an upthrow on the N.W. side. The position of these sandstones and shales in the Carboniferous series cannot be well made out at Eden Brows. There are, however, exposures of Carboniferous rocks (which seem to result from the influence of the same fault) a few miles to the west; and these Carboniferous rocks belong to the lower portion of the group.

Immediately north of Eden Brows the Permian rocks are again seen. As they occur on the east side of the river, in Fishgard Wood, they consist of the higher

members (the Corby sandstones); and on the west side of the Eden the gypsiferous red clays have been extensively worked. Another fault gives rise to the presence of these strata, which have a strike nearly E. and W. This latter fault, having a direction nearly parallel to the strike of the strata, can be well seen in Shalk beck near Curthwaite Station, on the Maryport and Carlisle Railway, where it exhibits a downthrow on the north side.

On the Arenig and Llandeilo Rocks of St. David's. By HENRY HICKS, *F.G.S.*

The author mentioned that the object intended in the paper was to follow out the succession of the rocks in the neighbourhood of St. David's, commenced in previous papers communicated at various times to the British Association. By the present paper the section was completed to the top of the Llandeilo series.

The author divided the Arenig group into an upper and lower series, and the Llandeilo group also in the same manner, believing that in each case there was sufficient evidence to enable him to do so.

The *Lower Arenig Series*, it was stated, occur as black slates and flags, about 1000 feet in thickness, and exposed at the north end of Ramsey Island and at Whitesand Bay, resting conformably in the former place on Tremadoc rocks, but separated from them in the latter by a fault. They are characterized by a large number of species of dendroid Graptolites, as well as by numerous species of trilobites entirely restricted to the series.

The *Upper Arenig Series* occur as fine-grained, soft, black shales, also about 1000 feet in thickness. They are found at the south end of Ramsey Island and at Whitesand Bay, where they rest conformably on the Lower Arenig series, and again on the north coast of Pembrokeshire, where they support the Lower Llandeilo rocks of Aberiddy Bay. The Graptolites of this series are totally distinct from those found in the lower beds, as are also all the other fossils. *Didymograptus bifidus, geminus*, and *affinis* are characteristic of this zone.

The *Lower Llandeilo Series*, the lowest rocks recognized by Sir R. Murchison in the typical Llandeilo district, and hence called by him Lower Llandeilo, occur at St. David's as black slates and hard grey flaggy sandstones with siliceous schist and beds of felspathic ash at the lower part, and as dark slates and flags, with numerous calcareous bands in the upper. They are about 1500 feet in thickness, and are chiefly found on the south coast of Aberiddy Bay, resting conformably on the upper Arenig rocks. The most characteristic fossils of these beds are *Didymograptus Murchisoni, Diplograptus pristis, Asaphus tyrannus, Calymene cambrensis*, and *Illænus perovalis*.

The *Upper Llandeilo Series* occur as black slates and flags several thousand feet in thickness, forming several folds of strata in a direction north of Aberiddy Bay, at which place they rest conformably on the Lower Llandeilo series. The typical fossils are *Ogygia Buchii, Barrandia Cordayi, Calymene duplicata, Cheirurus Sedgwickii, Trinucleus fimbriatus, Ampyx nudus*, and *Lingula Ramsayi*.

The author doubted whether any other spot hitherto examined in Britain could show so continuous a section of these rocks; still he believed that there was ample evidence to prove, from researches made in other parts of Wales and Shropshire, that the succession here made out was in most of its important details capable of being applied to many other districts.

On some Graptolites from the Upper Arenig Rocks of Ramsey Island, St. David's. By JOHN HOPKINSON, *F.G.S., F.R.M.S.*

At the Meeting of the British Association at Brighton last year the author had announced the discovery of a considerable number of Graptolites in the Arenig rocks of Ramsey Island and Whitesand Bay, near St. David's, and had shown that these rocks were more nearly allied by their Graptolites to the Quebec rocks of Canada than to their British representatives, the Skiddaw slates of Cumberland and the Arenig rocks of Shelve.

Since then a new series of fossiliferous beds had been discovered on Ramsey Island; and the Graptolites collected in them had been intrusted to the author for

determination. Owing to their fragmentary condition the following species only could be determined:—

Didymograptus affinis, *Nich.*	Diplograptus dentatus, *Brong.* sp.
—— bifidus, *Hall.*	(=D. pristiniformis, *Hall*).
—— geminus, *His.* sp.	—— mucronatus, *Hall.*
—— patulus, *Hall.*	Climacograptus scalaris, *Linn.* sp.

The evidence afforded by these species was considered to be decidedly in favour of the view that these new Ramsey-Island beds were of Upper Arenig age, and therefore higher than those previously known.

Comparing the Graptolites of the Skiddaw slates of Cumberland and the Arenig rocks of Shelve with those of the Lower and Upper Arenig rocks of Ramsey Island, there appeared upon the whole to be a parallel succession of species in the Shelve and Ramsey-Island rocks; while the Skiddaw series seemed to be more nearly related to the upper than to the lower Ramsey-Island beds; and it was inferred that the Skiddaw slates, which have hitherto been considered our oldest graptolite-bearing rocks, are of more recent age than the lowest graptolitiferous rocks of St. David's.

On the Occurrence of numerous Species of Graptolites in the Ludlow Rocks of Shropshire. By JOHN HOPKINSON, *F.G.S., F.R.M.S.*

Until recently only two species of Graptolites, *Monograptus* (*Graptolithus*) *priodon* and *M. colonus*, were believed to occur in the Ludlow rocks of Shropshire. In 1868 Dr. Nicholson added to these a new species of *Ptilograptus*, and mentioned the presence of an additional species of *Monograptus*. These had been collected by Mr. Lightbody of Ludlow, who had also found a few other species in these rocks.

In the course of an excursion of the Geologists' Association to the Silurian rocks of Shropshire in July 1872, and during a subsequent visit which the author had paid to Ludlow and its neighbourhood, several other species had been found, and some information on the distribution of the species had been elicited.

While, however, the number of species known to occur in the Ludlow rocks has been greatly augmented by these researches, one or two forms, hitherto supposed to be characteristic of one or the other division of these rocks, had not been found in them. Not a single specimen of *Monograptus priodon* had been seen in the Ludlow rocks, all that were found being from the Wenlock shale; and not a single Graptolite had been detected in the Upper Ludlow rocks, although two species, *M. colonus* and *M. priodon*, had been stated to be of common occurrence in both the Lower and Upper Ludlow. The Graptolites, with the exception of a species or two of the Dendroidea, appeared to have died out for ever in the Aymestry limestone, in which a few indeterminable fragments only have been found.

The following species had been determined:—

Rhabdophora.

Monograptus bohemicus, *Barr.*	Monograptus incurvus, sp. nov.
—— capula, sp. nov.	—— leintwardensis, sp. nov.
—— chimæra, *Barr.*	—— Nilssoni, *Barr.*
—— clavicula, sp. nov.	—— Salweyi, sp. nov.
—— colonus, *Barr.*	—— serra, sp. nov.

Dendroidea.

Ptilograptus anglicus, *Nich.*	Ptilograptus (*vel* Dendrograptus) Nicholsoni, sp. nov.
—— elegans, sp. nov.	

These species were found to be restricted in their range in time, and to characterize the same zones at distances wide apart. Some progress had been made towards working out this interesting question; but a more lengthened investigation of the Lower Ludlow rocks in the Ludlow area was considered to be necessary before any definite conclusion could be arrived at.

On the Occurrence in the Yoredale Rocks of Wensleydale of Fish and Amphibian Remains. By W. HORNE.

The remains occurred in thin limestones above and contiguous to the main limestone. Among the fossils were teeth of *Cladodus* and *Pleurodus*, and bones of the limbs of a Labyrinthodont Amphibian.

On the British Palæozoic Arcadæ. By J. LOGAN LOBLEY, *F.G.S.*

In this paper the results of an examination of the described species of Lamellibranchiata attributed to the family Arcadæ, and occurring in British Palæozoic rocks, were given.

After proposing that the sinupallial genera which have hitherto been included in Arcadæ should be removed from that family and constitute a separate group, the author discussed the claims of the various generic distinctions which authors had sought to establish, and thought the following genera might be admitted as having representatives in the Palæozoic strata of the British Islands:—*Arca* (L.), *Cucullæa* (Lam.), *Macrodon* (Lycett), *Nucula* (Lam.), *Ctenodonta* (Salter), *Cucullella* (M'Coy), *Glyptarca* (Hicks), *Palæarca* (Hall.)—the species of Arcadæ which had been assigned by various authors to *Byssoarca, Cleidophorus, Cypricarditis, Cyrtodonta, Megambonia, Pullastra, Tellinomya, Vanuxemia*, &c. being given to one or other of the before-mentioned genera.

The following summary gives the number of species admitted in each genus, with its stratigraphical range in the Palæozoic rocks:—

Arca, 9 species..........	Ludlow, Carboniferous Limestone.
Cucullæa, 10 species	Middle Devonian, Upper Devonian, Carboniferous Limestone.
Macrodon, 1 species	Permian.
Nucula, 1 species........	Permian.
Ctenodonta, 41 species....	Tremadoc, Llandeilo, Caradoc, Lower Llandovery, Upper Llandovery, Wenlock, Ludlow, Lower Devonian, Middle Devonian, Upper Devonian, Carboniferous Limestone, Coal-measures.
Cucullella, 4 species......	Caradoc, Upper Llandovery, Ludlow.
Glyptarca, 2 species	Tremadoc.
Palæarca, 14 species	Tremadoc, Llandeilo, Caradoc, Upper Llandovery, Ludlow.

Total 82 species, having the following distribution:—Tremadoc, 6; Llandeilo, 3; Caradoc, 17; Lower Llandovery, 2; Upper Llandovery, 11; Wenlock, 2; Ludlow, 7; Lower Devonian, 1; Middle Devonian, 2; Upper Devonian, 11; Carboniferous Limestone, 29; Coal-measures, 2; Permian, 2.

On a Horn and Bones found in a Cutting in a Street in Maidenhead, Berks. By T. MOFFAT, *M.D., F.G.S.*

The horn and bones were found imbedded in flint gravel about six feet from the surface. They appeared to be much mineralized. There are cuts upon the horn, apparently made when it was fresh and for the purpose of separating it from the skull. The cuts seem to have been made with an edged metallic tool.

On Geological Systems and Endemic Diseases. By T. MOFFAT, *M.D., F.G.S.*

The author stated that the results given in this confirmed what he had stated in his former papers, viz. that goître and anæmia are endemic on the Carboniferous system, while they are absent on Cheshire or New Red Sandstone. He wished it to be understood, however, that the observations were made only in the district in which he resided.

Referring to a suggestion made by Mr. Lebour, of the Geological Survey, in a paper "On the Geological distribution of goitre in England and Wales," that the cause of goître "is the metallic impurities in the water," and a statement "that it prevailed most where ferruginous water occurred," the author states that iron medicinally administered produces beneficial effects, but when ferruginous water is taken daily it produces a low state of health, and in that way might predispose to the formation of goître; but such water would not cause anæmia. He observes that it is very doubtful, however, if water containing iron is ever used as a potable water or for culinary purposes, one grain per gallon rendering it unfit for making an infusion of tea.

In the neighbourhood in which he lives such water is avoided. In the performance of his duties as Medical Officer of Health, he had chemically examined ten public wells in his district; and he did not detect a trace of iron in one of them, from which he concludes that goître, which is very prevalent in the locality, cannot be caused by ferruginous water.

As anæmia is a state of the system in which oxide of iron is deficient in the blood, and as goître appears at a time of life and under conditions of the system when a maximum quantity of nutritious food is required, he concludes that where there is a deficiency of iron and phosphates, or nutritive salts in the food, these forms of disease will prevail.

By chemical analysis he has shown that iron and the phosphates are deficient in wheat grown upon the Carboniferous system compared with that grown upon the New Red Sandstone. Soils, he observes, are formed by the disintegration of the rocks or formations upon which they lie, and consequently they consist of the same ingredients. The colouring-matter of the Cheshire sandstone is oxide of iron; and the soil upon it is thoroughly impregnated with that oxide. The Carboniferous system is not impregnated with it; oxide of iron is not so thoroughly diffused throughout this system as it is in the New Red Sandstone; so, compared with the latter, there is a deficiency of iron in the soil upon the former.

To the above rule he states there are, however, exceptions, as soils do not always consist of the disintegrated rocks upon which they rest. In a district with which he is well acquainted the geological formation is Millstone-grit, yet the soil upon it is as highly coloured with oxide of iron as that upon New Red Sandstone at no great distance from it. In this district goître and anæmia are unknown. He concludes that goître and anæmia do not occur in a district having a soil containing a maximum quantity of oxide of iron and phosphates, no matter what the system is upon which it rests.

On the Ammonitic Spiral in reference to the power of Flotation attributed to the Animal. By John Phillips, *M.A., F.R.S., D.C.L. Oxon., LL.D. Cambr. and Dublin, Professor of Geology, Oxford.*

The author, while considering the subject in connexion with the recent *Nautilus pompilius* and *Spirula* and with many fossil genera, found a deficiency of data as to the proportion of the supposed air-chambers to the whole volume of the shell and the part of it occupied in life by the animal. To obtain such data he examined the spiral structure by means of principal sections on the plane of volution, and found that, omitting the earliest small volutions, the growth of the ammonite shell was in many species uniform, so that the proportion of the last chamber to the sum of all the preceding ones was nearly uniform; but among different species the character of the spiral differed. In one group the breadths of the volutions measured on a radius vector increased in geometrical proportion; in another the increase was in arithmetical proportion; between these two forms all ammonitic spirals appeared to be contained. The author then showed how, in the former group, the power of flotation, if it existed, would be uniform through life, but in the latter continually increasing. In order to see the exact bearing of this on the question of flotation, it would be necessary to determine some other points as to the thickness of shell and number of septa.

With respect to the further function attributed to these animals, that of rising and falling at pleasure in the sea, the author showed, by measuring the

siphuncle, that such a power of adapting the specific gravity of the shell must have been very limited; and he was disposed, on the whole, to believe that the old Cephalopods, in rising and falling, trusted more to their strong arms than to the filling and emptying of the pipe which connected the chambers. The subject is under investigation.

On the Ammonitic Septa in relation to Geological Time. By JOHN PHILLIPS, *M.A., F.R.S., D.C.L. Oxon., LL.D. Cambridge and Dublin, Professor of Geology, Oxford.*

The author, viewing the Ammonitidæ as a family extending in time from the Devonian to the Cretaceous period, proposed to examine into the genealogy of the proper genus called *Ammonites*. He showed that from a supposed ancestral origin in *Goniatites*, two lines of real or imaginary descent might be traced—one through *Ceratites* of the Muschelkalk to the Cassianic ammonites, another through the *Arietes* and other species of Lower Lias to the Upper Oolite and Cretaceous groups. In neither case is the genealogy proved between the Carboniferous and later families; but in each case the change of septal outline (or "suture") is from simple undulations to very complicated foliations. Such change, then, is only indicative of successive time as it is characteristic of successive physiological change. Instead of one development from *Goniatites*, the most convenient form of hypothesis, at present, would be to assume separate systems of development, each limited in time to different periods, but following the same course of physiological change. The same order of change occurs in the embryonic, young, and old shell of each species. (The author hopes to make a further communication.)

The Loess of Northern China, and its Relation to the Salt-basins of Central Asia. By BARON VON RICHTHOFEN, *Ph.D. (Berlin).*

Northern China is covered with a yellow earth which resembles the Loess of the valley of the Rhine in all essential properties. It is fine-grained and fusible, yet so solid as to form vertical cliffs and bluffs several hundred feet high, and distinguished by the complete absence of planes of stratification as well as a marked tendency to vertical cleavage. It resembles loam in composition (its chief ingredients being an argillaceous and ferruginous basis which contains very fine sand and carbonate of lime in varying proportions), but differs from that earth by possessing a highly porous and tubular structure. The tubes, which are very thin and usually incrusted with a fine calcareous film, occupy in general a vertical position, and ramify like the roots of grass. They cause the Loess to absorb water like a sponge, and prevent the existence of any lakes on its surface, or the issuing of springs from the body of the formation, although these are copious where the earth rests on rocks or stratified soil. The Loess encloses bones of land-animals and an abundance of well-preserved shells of terrestrial mollusca, but no marine or freshwater fossils. Calcareous concretions are always disseminated through it, and mostly arranged in well-defined layers, in which, as a rule, the longer axis of each nodule occupies a vertical position.

The Loess is peculiar to Northern China, no trace of it occurring in the southern provinces; it is observable on the side of Mongolia and Central Asia, just to the limit of the headwaters of those rivers which flow towards the sea, covering altogether an area of about 240,000 square miles. Within this area it spreads alike over low and high ground, from the level of the sea to altitudes of 8000 feet, its thickness varying from very little to upwards of 1500 feet. It smooths off the irregularities of the surface, and, by connecting with each other the crests of distant mountain-ranges, creates between them large trough-like basins with gently inclined slopes, the bottom of each of which is made up of stratified earth which otherwise resembles Loess in appearance and is strongly impregnated with alkaline salts. The sides of each basin are furrowed by innumerable and infinitely ramified gullies, which frequently attain the depth of 1500 feet. With the exception of the great alluvial plain adjoining the lower Hwangho, human habitations and

agriculture are confined in Northern China to the Loess, millions of people living in caves dug in that earth.

As regards the mode of origin of the Loess of China, it can neither be a freshwater deposit, which Pumpelly supposed it to be, nor a marine formation, which Kingsmill attempted to make it—not so much on account of the absence from it of either freshwater or marine fossils and the want of stratification, as because lacustrine strata could not possibly be deposited on the crests of the highest mountain-ranges and the most elevated portions of plateaux, while the theory of a marine origin would force us to presuppose Eastern Asia to have been submerged at least 8000 feet beneath the present sea-level in very recent time, an assumption against which there exists a great deal of direct evidence. The author next attempted to prove that the Loess is a subaërial deposit, and drew attention to the close similarity in the character of the surface between the Loess-basins of Northern China and the salt-basins of the steppes of Central Asia. From Pamir and the Karakorom to the headwaters of the large rivers flowing towards the seas which surround Asia on the north-east and south-east, a vast extent of country (exhibiting differences of altitude as great as any which occur in Europe) is made up of numerous basins without outward drainage, the surface of each of which slopes gently down from the crests or declivities of the surrounding mountain-ranges towards the lowest portion, which is filled with a salt lake or marsh. Each basin exhibits now the surface of an accumulation of débris, which smooths off the inequalities of the rocks below, but is unknown equally as to composition, structure, and thickness, because no portion below the smooth surface is exposed to view. Everywhere the soil is impregnated with salts, and therefore allows only of the growth of a steppe vegetation. Neither the salt lakes nor the steppe deposits have originated (as has been suggested) in the former submergence of the whole area beneath the sea, but are of subaërial origin. The products of decomposition of the mountain-ranges which constitute the skeleton of Central Asia, not being able to make their way to the sea, are deposited in the adjoining basins, partly by rain-water, which washes them off the rocks and distributes them equally over the gentle slopes, and partly by winds which carry large amounts of them away and, in the present time, frequently obscure for many days the atmosphere by the ingredients they carry in suspension, depositing them finally as fine dust over the surface. The substances which are thus mechanically distributed over the soil by either agency are retained there by the vegetation, and cause, in the course of centuries, the gradual raising of the surface; while the soluble products of decomposition are mainly collected in the central pool, where the evaporation of the water causes the gradual concentration of the solution; and at the same time stratified soil, similar in composition to the soil of the steppes, is deposited. If now in any one basin the rains, in consequence of slight climatal changes, cause a greater increase in the quantity of water than is lost by evaporation, the basin will gradually be filled and the water finally seek an outlet at the lowest place of the margin. With the gradual deepening of the channel the basin will be drained, and the affluents converging towards its lowest portion will cut deep gullies into the soil of the previous steppe, thus exposing its nature, and at the same time carrying off the salts with which it was impregnated.

A short sketch was then given of the evidence collected to show that the Loess-basins of Northern China have formerly been basins without outward drainage, and were provided, each of them, with a salt lake in its lowest portion, that they were gradually drained, one by one, towards the sea, and that this process, consequent on slow climatal changes, is still going on along the eastern limit of the salt-lake plateaux. In the Loess of Northern China is therefore exhibited the nature of the subaërial deposits which fill the salt basins of Central Asia; but, the salts being extracted from it, it yields all the conditions required for agriculture and the existence of civilized man.

Baron von Richthofen finally wished it to be distinctly understood as his opinion that Loess may have originated in different ways, and that he does not believe the theory which he has advanced as to the origin of the Loess of Northern China to be applicable in every case where Loess occurs.

Geology of the Country round Bradford, Yorkshire. *By* R. Russell, *C.E., F.G.S., H.M. Geological Survey**.

Lithological Description.

The country which the author described lies between the river Wharfe and Calder on the north and south, the towns of Leeds and Halifax on the east and west, having Bradford in the centre.

The measures included within this area belong to the Carboniferous series, together with a few patches of drift clay, and gravel, and the alluvial deposits in the river-valleys.

The Carboniferous rocks may be divided as follows:—

	feet.
Middle Coal-measures	850
Lower Coal-measures	1226
Upper Grit, or Rough Rock, with flags at base	180
Shales	110
Middle Grit in several beds	1400

Beginning with the lower beds, the author shortly described the lithological character of each group in chronological order.

The lower part of the Middle Grits consists of shale alternating with bands of sandstone. The upper portion is principally sandstone with thin bands of shale; and the lowest bed of this division is the thick and massive rock which forms Ilkley Crags and Otley Chevin.

The flags at the base of the Upper Grit are fine-grained and regularly bedded; but they are not always present.

The Upper Grit itself is a coarse-grained massive sandstone, varying from 80 to 180 feet in thickness. It generally occurs in one bed; but northwards it lies in two or three distinct beds.

The Lower Coal-measures contain five workable seams of coal, ten thin coals which occasionally attain a thickness of 1 ft. 2 in. and 1 ft. 8 in., and several beds of sandstone, the principal of which are known under the names of the Elland Flagstone and the Oakenshaw rock.

The five principal coals and two sandstones may be described thus:—

The Halifax Soft-bed coal maintains a very constant thickness of 1 ft. 4 in., to 1 ft. 8 in. from Halifax northwards, but eastwards it diminshes to a band a few inches thick.

The Halifax Hard-bed coal varies from 2 ft. 3 in. in the south to 1 ft. 4 in. in the north, and like the Soft Bed thins out eastwards to a thin band.

The Fireclay below the Gannister, on which the coal lies, is often worked along with the coal, being from 3 to 6 ft. thick.

The Elland Flagstone includes a group of sandstones, which, being in general thin-bedded and flaggy, give the name to the rock. It forms large spreads on the higher ground around Northowram; and west and north of Bradford the 60-yards rock of Thornton seems to unite with it and form the thick sandstone at Gaisby Hill.

The Better-bed coal is one of the most important and valuable coals in the neighbourhood, attaining a thickness of 3 feet at Horton; but the average thickness is about 1 ft. 8 in.; much value is set on this coal by the Iron Companies in the district.

The Black-bed coal is of a softer nature and inferior quality, 2 ft. 4 in. to 2 ft. 6 in. thick at Low Moor; but at Farnley and Beeston the lower part of the seam is converted into an impure stone coal. The value of this coal is enhanced by the ironstone-bearing shale which overlies it. The layers of ironstone are imbedded in a carbonaceous shale; and the average thickness of good ironstone will be about 5 or 6 inches, that portion of it known as the "middle balls" being the richest in metallic iron.

The Oakenshaw rock is a well-marked and distinct sandstone over the whole

* See 'Iron,' Nos. 39 & 40, vol. xi. New Series, pp. 458 & 491; also Geological Survey Memoir on the Yorkshire Coalfield.

district from Mirfield to Hunsworth, coarse in grain, thick, and in many cases false-bedded.

The Beeston-bed coal is the representative of an interesting series of coals, which occur in the south as the Shertcliffe-bed coal and two coal bands, and then as the Churwell Thick and Thin coals, and finally as the Beeston bed, uniting the qualities as well as the thickness in one seam.

The Middle Coal-measures contain eleven principal coal seams and two sandstone rocks, which are worthy of notice.

The Blocking coal, the horizon of which indicates the division between the Lower and Middle Coal-measures, is a coal which has been most extensively worked over a great portion of this area; it varies in thickness from 1 ft. 3 in. to 1 ft. 8 in., and is of a very good quality.

The Three-quarters or Middleton 11-yards coal is a constant coal, but it is thin and of an inferior quality within our present limits.

The Cromwell or Middleton Main coal is a valuable coal, and is generally a soft coal, but at Birstall part of the seam is converted into Cannel coal. The thickness is from 1 ft. 7½ in. to 4 ft. 6 in.

The Green-Lane or Middleton Little coal, near Dewsbury, is only about 9 inches or 1 foot thick; but northwards it improves both in quality and thickness, being as much as 2 ft. 6 in. to 3 ft. in the district around Morley, and contains a band of semi-anthracitic coal which is used as a steam coal.

The Brown-metal coals, three in number, continue constant, though the manner of their occurrence is varied.

At Dewsbury we have the series complete, while at White Lee the two upper beds unite and form the 2-yards coal, a parting of about 1 ft. 6 in. intervening between the two seams. These two coals are again separated at Bruntcliffe by about 28 feet of shales, while the lowest seam is represented by a band of black shale.

The Birstall Rock is contained in the measures which lie between these coals and the Flockton Thin coal. It is a very irregular sandstone, but is largely developed at Batley Carr, Carlinghow, and Birstall, where it attains a thickness of 100 feet. Much good building-stone is obtained from this rock.

The Flockton Thin or Adwalton Black bed is about 3 feet thick, and contains a layer of clay from 2 to 4 inches thick a few inches from the top of the seam. The seam is very regular, and the quality of an average kind; and it is used as a soft coal for gas-making.

The Adwalton Stone coal: the upper portion of this seam is a good cannel coal 6 to 10 inches thick, the total thickness of the bed being from 3 ft. to 3 ft. 6 in. The roof shale of this coal is recognizable throughout the whole of the Yorkshire coal-field, being a black shale containing ironstone nodules which are one mass of *Anthracosia*, and is locally known in this district as the "Cockle-shell bed."

The Joan coal varies from 2 ft. 3 in. to 1 ft. in thickness, but has not been much worked, though it is of good quality.

The measures which lie between this coal and the Haigh-Moor coals contain the sandstone known as the Thornhill rock. This sandstone is regular and uniform in occurrence and thickness, and will compare in this respect with the sandstones of the Lower Coal-measures. Good and durable building-stone is obtained from it.

The Low and Top Haigh-Moor coals are separated from each other at Pildacre by about 30 feet of shales; northwards the Low coal becomes deteriorated and the Top coal continues as the Haigh-Moor coal of the country to the north and north-west.

The Warren-house or Gawthorpe coal is only present over a very small area near Chidswell, and is from 7 to 8 feet thick.

The Lie of the Measures.

By the aid of certain natural lines which occur within this area, such as the lines of faults and features of the country, we are enabled the more easily to describe the lie of these beds.

Beginning with the country on the south-west of the fault from Clifton Common through Bailiff Bridge to Denholme Clough, the Rough rock stretches away westwards from under the Coal-measures, while between the top line of that rock

and the fault we have measures as high as the Crow coal, the coals above the Elland Flagstone putting in a little way west of the fault. This area is broken up by a number of smaller faults. The Bailiff-Bridge fault begins at Clifton Common, increases to 62 yards at Norwood Green, and to 150 or 200 yards at Denholme Clough.

On the north-east side of the Bailiff-Bridge fault and south of the Bradford southerly and Harper-Gate faults to the river Calder, there is a tract of country which is crossed by a number of large faults running nearly north-east and south-west and north-west and south-east, and a set of smaller faults the direction of which is approximately east and west. Between the Bradford southerly and Tong faults and one of these north-east and south-west faults, viz. the Birkenshaw fault, all the beds crop out from the Better-bed to the Middleton Main coal which caps the top of Westgate Hill. On the downcast or south-east side of this fault we have measures up to the base of the Thornhill rock; and this is again thrown down on the south-east by the Bruntcliffe fault, the amount of throw being about 80 yards; and the Haigh-Moor coal is brought in at Soothill by the Upper-Batley fault, but is thrown out again at Hanging Heaton on the upcast side of the Staincliffe fault, once more occurring over the Thornhill rock at Pildacre Hill east of Dewsbury.

On the north side of the Bradford southerly and Harper-Gate faults, the country is also intersected by many faults, which would require too much space to describe in any detail; but between these faults and the top line of the Upper Grit from Wilsden to Thackley we have the beds from the Better-bed coal to the Halifax Soft coal, while measures nearly as high as the Shertcliffe bed occur in the triangular space between the Egypt, Fairweather-Green and Leventhorpe-Mill faults, and in the trough between the Bradford northerly and the Throstle-nest faults, extending from Chellon Dean to Fagley.

The Upper Grit, rising from under the northern edge of the Coal-measures, stretches away over the high ground to Yeadon and Rumbles moors, surmounted at Baildon Common and Rawdon by outliers of the Lower Coal-measures, while the Middle Grits, consisting of alternating bands of sandstone and shale, run along the lower slopes of the valleys.

The outlier at Baildon contains beds up to the base of the flagstone group, which lie in regular succession over the Rough rock at Baildon Bank, and are brought against the grit on the north by the continuation of the Row fault.

The Rawdon outlier is connected with the main portion of the coal-field by the extension to the north-east of the belt between the Bradford northerly and southerly faults, the beds cropping out on the east and west sides of this belt above the Upper Grit, and bounded on the north by a fault running westward through Rawdon Common.

The Middle Grits rise to the surface north of Yeadon and Rumbles moors, form the magnificent escarpment from Addingham Crag by Ilkley Crags and Otley Chevin to Bramhope Bank, giving a grandeur to this portion of the Wharfe valley which, in scenery of this kind, is hardly to be surpassed.

Boulder-beds.—These deposits consist of Boulder-clay and gravels—the gravels being of two kinds, those found on the high grounds, and those found in the valleys—together with a stiffish clay containing fragments of local stones and which is probably lacustrine in its origin.

The Boulder-clay is composed of blackish, bluish, and yellowish clay containing fragments and blocks of sandstone, grit, limestone, and shale, the blocks of limestone being in many cases scratched, polished, and angular, though in other cases they are well rounded as well as striated; but it is hardly possible to separate the one from the other. The drift in the Aire basin contains no fragments which may not have come from the rocks within the watershed—with one exception so far as the author is aware; and that is in the valley at and just south of Bradford, where he found a few pebbles of trap and ash rock as far up towards the watershed between the Aire and Calder as Rooley and Great Horton, and one block of coarse granite out of the drift clay on the east side of Bowling Lane between Bowling House and The Oaks.

The normal condition of the Boulder-clay in the valleys of the Aire and Wharfe being as previously described, would lead us to infer that it has been formed by

some cause acting locally, though it might probably be due to a universal ice-sheet.

The fact of these beds being thickest in the main valleys and extending into the tributary valleys, the high land being usually free from them, shows the general contour of the country to have been much the same in preglacial times as it is now.

The long ridges of gravel which extend in a somewhat broken and curved line from Burley Moor to Hawkesworth, are composed of limestone gravel, forming a bank about 60 yards wide and 10 to 20 feet high, being at the north end 1150 feet and at the south 600 feet above the sea-level, thus running across the ground irrespective of contour, and seem to be undoubted Eskers.

The mounds of gravel which occur in the valley of the Aire at Bingley are composed of limestone gravel and boulders, the greatest proportion of which are well-rounded pebbles with faint traces of striæ upon them; this would point to re-arranged drift, or drift which was subjected to tides and currents during deposition. This is further exemplified by the stratification being both up and down the valley, and might have been formed when the land stood 300 or 400 feet below its present level, the valley of the Aire being then an inlet of the sea up which the tide ebbed and flowed, and by its action formed these mounds from previously existing material.

River Deposits.—Gravel occurs at Exley Hall and Kirklees Park, 150 feet above the present river, and is supposed to be of river formation.

The river-terraces consist of sand, gravel, and clay, and occur in many places along the course of the main rivers, as at Thornhill Lees in the valley of the Calder, Calverley in the valley of the Aire, and in the valley of the Wharfe almost continuously from Burley to Poole.

The recent alluvium is composed of fine loamy clay, sand, and gravel. Many large trees have been found imbedded in this alluvium in the valley of the Calder, some of them being from 2 to 3 feet in diameter, and 60 feet in length.

On the Occurrence of Elephant-remains in the Basement Beds of the Red Crag. By J. E. Taylor, *F.L.S., F.G.S.*

The author exhibited a tooth from the basement bed of the Red Crag, where *Mastodon* and other early Pliocene or late Miocene mammalia are met with. It had been contended that the elephant-teeth did not come from this bed; but the author denied this from personal experience. The tooth in question was very peculiar, from the width between the ridges, and its singular resemblance to the *Mastodon* type.

On the Correspondence between some Areas of apparent Upheaval and the Thickening of subjacent Beds. By W. Topley, *F.G.S., Geological Survey of England.*

The author first referred to some known facts as to the thinning of strata in certain directions, and he drew attention to the coincidence between the direction of this thinning and the direction of the general dip. The south-easterly attenuation of the Oolites of Central England (long since proved by Prof. Hull) and the thinning-out of the Lower Cretaceous rocks under London, were the cases most fully dwelt upon. Illustrations were also drawn from the Carboniferous rocks of Yorkshire and Derbyshire, and the Lower Cretaceous rocks on the west of the Paris basin.

It was shown, as regards the areas described, that the rise of the beds is in that direction in which the underlying beds obtained their greatest thickness. It has hitherto been assumed that the rise and dip of strata is due to movements of the earth's crust; but the author pointed out that, in the instances alluded to, this is an erroneous conclusion. Only a small portion of the apparent upheaval could be due to this cause, whilst in some cases it seemed that the whole of it could be explained by the thickening of subjacent beds. The author concluded by pointing out the important bearing of these facts upon some current geological theories, referring especially to the supposed connexion between the "upheaval" of the Weald and the existing valley-systems of that area.

On the Whin Sill of Northumberland. *By* W. Topley, *F.G.S.*, *and* G. A. Lebour, *F.G.S.*

This paper gave the results of work by the authors during the progress of the Geological Survey, and it was communicated to the Section by permission of the Director-General of the Survey.

The Whinstone or Basalt of the north of England occurs in two forms, either as *dykes* cutting through the rocks, or as *beds* lying amongst them. The intrusive character of the former is undisputed; but there has always been considerable uncertainty as to the character of the latter. The authors affirmed that in Northumberland there could be no doubt whatever that the sheet or sheets of basalt known as the "Whin Sill" were intrusive, and that the trap had been forced through the rocks long after their deposition and consolidation. The evidence of this was found in the altered nature of the rocks above the whin, especially when they consist of shales, and in the fact that the whin does not lie at one uniform level amongst the sedimentary strata, but frequently comes up in bosses, cutting through the rocks, and shifting its relative position amongst them to the extent of 1000 feet or more in short distances.

An account of the literature of the subject was given; and reference was particularly made to a paper by Sir W. C. Trevelyan, published in 1823 in the 'Wernerian Transactions,' in which the intrusive nature of the basalt of North Northumberland was clearly shown.

A note by Mr. S. Allport, F.G.S., was appended to the paper, giving an account of the microscopic structure of the basalt, showing it to be precisely similar in character to the intrusive sheets of trap which occur in the coal-field of the midland counties.

Note on the Occurrence of Thanet Sand and of Crag in the S.W. part of Suffolk (Sudbury). *By* W. Whitaker, *B.A.* (*Lond.*), *of the Geological Survey.*

The author had observed near Sudbury some sections proving the existence of Thanet Sand in that district. None had previously been observed on the northern outcrop of the London basin. The sand is fine and loamy, just like that of West Kent. The author also noticed the occurrence of Crag at Sudbury, at many miles from, and at a higher level than, any previously known.

On some Specimens of Dithyrocaris *from the Carboniferous Limestone Series, East Kilbride, and from the Old Red Sandstone (?) of Lanarkshire; with Notes on their Geological Position &c.* *By* Henry Woodward, *F.R.S., F.G.S.*, *and* Robert Etheridge, jun., *F.G.S.*

The authors described nine specimens of Phyllopodous Crustaceans, eight of which are from the Carboniferous series of East Kilbride, and the remaining form from the Old Red Sandstone (?) of Lanarkshire. They are all referable to the genus *Dithyrocaris*; and the authors described four new species, namely:—

Dithyrocaris granulata, W. & E. Carboniferous Limestone series, East Kilbride.
—— *ovalis*, W. & E. Carboniferous Limestone series, East Kilbride.
—— *glabra*, W. & E. Carboniferous Limestone series, East Kilbride.
—— *striata*, W. & E. Old Red Sandstone, Lanark.

The other examples are referred to Dr. Scouler's *Dithyrocaris tricornis* and *D. testudinea*, both of which were also obtained from the Carboniferous Limestone series of East Kilbride.

With regard to *D. tricornis*, one of the authors (Mr. Woodward) had made the interesting discovery that the carapace in Dr. Scouler's specimen was folded together, and that Dr. Scouler had mistaken the true *anterior* border of the carapace—the three spines, on which the specific diagnosis was founded, being really at the *posterior* end of the carapace—the body-segments having been twisted out of

place, as constantly happens in *Ceratiocaris papilio*, Salter, from the Upper Silurian of Lesmahagow (see 'Siluria,' 4th edit. 1867, p. 236, Fossils (66), fig. 1, and footnote thereon). The maxillæ, which are preserved *in situ* in Dr. Scouler's specimen, indicate the true anterior end of the carapace.

New Facts bearing on the Inquiry concerning Forms intermediate between Birds and Reptiles. By Henry Woodward, *F.R.S., F.G.S., of the British Museum.*

In this paper the author drew attention to the great *hiatus* existing at the present day between Birds and Reptiles, and referred to the researches of Prof. Huxley and others in order to show that both the Ornithic and Reptilian types were superstructures raised on the same ground-plan, and that the Chelonia, Ichthyosauria, Plesiosauria, Pterosauria, and Lacertilia differ fully as much from one another as they do from the class Aves.

To associate all these forms together under one great Class, the Sauropsida, as proposed by Prof. Huxley, is therefore fully justified by the common structural affinities which they present.

Among existing birds the *Ratitæ* or Struthious birds come nearer to Reptilia than any other group; and their wide distribution attests their great antiquity, whilst their fossil forms occur as low down as the Eocene. The author pointed out that the Pterosauria only presented an adaptive modification of Avian structures, but did not help to bridge over the gap which exists between these two divisions.

He cited the remarkable Mesozoic bird (the *Archæopteryx*) as affording a more generalized type of structure than any other known genus of Aves, the tail being composed of twenty free vertebræ, and the digits of the wings being armed with claws.

Two birds had also been described by Prof. O. C. Marsh from the Cretaceous shales of Kansas, remarkable for possessing numerous teeth in both jaws, implanted in distinct sockets, and also biconcave vertebræ.

Lastly, Prof. Owen had just described a new and remarkable bird from the London Clay of Sheppey, the *Odontopteryx toliapicus*, having very prominent denticulations of the alveolar margins of the jaws, which, although not true teeth, no doubt subserved the function of those prehensile organs.

From the extreme rarity of all terrestrial-animal remains preserved in a fossil state, it may be justly concluded that many more such archaic birds with reptilian modifications actually existed in the Mesozoic epoch, although they may never be discovered by geologists.

The author then referred to the instances of fossil Reptilia which show remarkable ornithic modifications—as, for example, the singular *Compsognathus longipes* from Solenhofen, a lizard which, from its peculiar conformation, must have hopped or walked in an erect position, after the manner of a bird, to which its long neck, small head, short and diminutive anterior limbs gave it an extraordinary resemblance.

From the researches of Mantell, Owen, Phillips, Huxley, and Hulke in England, Cope, Leidy, and other anatomists in America, it would appear that the huge Dinosauria, the *Iguanodon, Megalosaurus*, &c., had also diminutive fore limbs and largely developed hind limbs, whilst from the form of the pelvic bones and the anchylosis of the sacral vertebræ, there can be little doubt they walked in an almost erect position—a conclusion which the bipedal tracks discovered by Mr. S. H. Beckles tend to confirm.

The author then described a remarkable lizard, the *Chlamydosaurus Kingii* from Australia, which habitually runs upon its hind legs, a mode of progression which its disproportionately short fore limbs at once suggest as its natural position; and as its habits are known to have been observed by Mr. Gerard Krefft and other naturalists, it affords a most valuable living illustration of a Mesozoic type approaching birds on the Reptilian side, as the Struthious Birds approach reptiles on the Avian side.

Some singular tracks from Solenhofen were referred to, which must have been

made by a bipedal reptile, like *Compsognathus*, or by a reptilian-like bird, such as *Archæopteryx*, having a long rat-like tail.

Mr. Woodward thinks the bipedal tracks on the Connecticut sandstones are to be satisfactorily explained by the conclusion which we are now justified in forming, that they were left by Avian-like Reptiles, although we have not as yet discovered their fossil remains.

BIOLOGY.

Address by George J. Allman, *M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., F.L.S., President of the Section.*

For some years it has been the practice at the Meetings of this Association for the special Presidents to open the work of their respective Sections with an Address, which is supposed to differ, in the greater generality of its subject, from the ordinary communications to the Sections. Finding that during the present Meeting this duty would devolve on myself, I thought over the available topics, and concluded that a few words on the Present Aspect of Biology and the Method of Biological Study would best satisfy the conditions imposed.

I shall endeavour to be as little technical as my subject will allow; and though I know that there are here present many to whom I cannot expect to convey any truths with which they are not already familiar, yet in an Address of this kind the speaker has no right to take for granted any large amount of scientific knowledge in his audience. Indeed one of the chief advantages which result from these Meetings of the British Association consists in the stimulus they give to inquiry, in the opportunity they afford to many of becoming acquainted for the first time with the established truths of science, and the initiation among them of new lines of thought.

And this is undoubtedly no small gain; for how many are there who, though they may have reaped all the advantages which our established educational systems can bestow, are yet sadly deficient in a knowledge of the world of life which surrounds them. It is a fair and wonderful world, this earth on which we have our dwelling-place; and yet how many wander over it unheedingly! by how many have its lessons of wisdom never been read! how many have never spared a thought on the beauty of its forms, the harmony of its relations, the deep meaning of its laws!

And with all this there is assuredly implanted in man an undying love of such knowledge. From his unshaken faith in causation he yearns to deduce the unknown from the known, to look beyond what is at hand and obvious to what is remote and unseen.

Conception of Biology and Function of the Scientific Method.

Under the head of Biology are included all those departments of scientific research which have as their object the investigation of the living beings, the plants and the animals, which tenant the surface of our earth, or have tenanted it in past time.

It admits of being studied under two grand heads—Morphology, which treats of Form, and Physiology, which treats of Function; and besides these there are certain departments of biological study to which both Morphology and Physiology contribute, such as Classification, Distribution, and that department of research which is concerned with the origin and causes of living and extinct forms.

By the aid of observation and experiment we obtain the elements which are to be combined and developed into a science of living beings; and it is the function of the scientific method to indicate the mode in which the combinations are to be effected, and the path which the development must pursue. Without it the results gained would be but a confused assemblage of isolated facts and dis-

connected phenomena; but, aided by a philosophic method, the observed facts become scientific propositions, what was apparently insignificant becomes full of meaning, and we get glimpses of the consummate laws which govern the whole.

I shall leave the consideration of Biology in its purely physiological aspect to the President of the Physiological Subsection, and shall here confine myself to those departments which are more or less controlled by morphological laws.

Importance of Anatomy.

The first step in our morphological study of living beings is to obtain an accurate and adequate knowledge of the forms of the individual objects which present themselves to us in our contemplation of the animal and vegetable kingdoms. For such knowledge, however, much more is needed than an acquaintance with their external figure. We must subject them to a searching scrutiny; we must make ourselves familiar with their anatomy, which involves not only a knowledge of the forms and disposition of their organs, internal as well as external, but of their histology or the microscopic structure of the tissues of which these organs are composed. Histology is nothing more than anatomy carried to its extreme term, to that point where it meets with the morphological unit, the ultimate element of form, and the simplest combinations of this out of which all the organs in the living body are built up.

Among the higher animals Anatomy, in the ordinary sense of the word, is sufficiently distinct from Histology to admit of separate study; but in the lower animals and in plants the two become confounded at so many points as to render their separate study often impracticable.

Now the great prominence given to Anatomy is one of the points which most eminently distinguish the modern schools of Biology.

Development.

Another order of morphological facts of no less importance than those obtained from anatomical study is derived from that of the changes of form which the individual experiences during the course of its life. We know that every organized being commences existence as a simple sphere of protoplasm, and that from this condition of extreme generalization all but the very lowest pass through phases of higher and higher specialization, acquiring new parts and differentiating new tissues. The sum of these changes constitute the development of the organism; and no series of facts is more full of significance in their bearing on biological science than that which is derived from the philosophic study of Development.

Classification an Expression of Affinities.

Hitherto we have been considering the individual organism without any direct reference to others; but the requirements of the biological method can be satisfied only by a comparison of the various organisms one with the other. Now the grounds of such comparison may be various; but what we are at present concerned with will be found in anatomical structure and in developmental changes; and in each of these directions facts of the highest order and of great significance become apparent.

By a carefully instituted comparison of one organism with another, we discover the resemblances as well as the differences between them. If these resemblances be strong and occur in important points of structure or development, we assert that there is an affinity between the compared organisms, and we assume that the closeness of the affinity varies directly with the closeness of the resemblance.

It is on the determination of these affinities that all philosophic classification of animals and plants must be based. A philosophic classification of organized beings aims at being a succinct statement of the affinities between the objects so classified, these affinities being at the same time so set forth as to have their various degrees of closeness and remoteness indicated in the classification.

Affinities have long been recognized as the grounds of a natural biological classification; but it is only quite lately that a new significance has been given to them by the assumption that they may indicate something more than simple

agreement with a common plan—that they may be derived by inheritance from a common ancestral form, and that they therefore afford evidence of a true blood-relationship between the organisms presenting them.

The recognition of this relationship is the basis of what is known as the Descent Theory. No one doubts that the resemblances we notice among the members of such small groups as those we name species are derived by inheritance from a common ancestor; and the Descent Theory is simply the extension to the larger groups of this same idea of relationship.

If this be a true principle, then biological classification becomes an exposition of family relationship—a genealogical tree in which the stem and branches indicate various degrees of kinship and direct and collateral lines of descent. It is this conception which takes classification out of the domain of the purely morphological.

Affinity determined by the study of Anatomy and Development.

From what has just been said, it follows that it is mainly by a comparison of organisms in their anatomical and developmental characters that their affinities are discoverable. The structure of an organism will, in by far the greater number of cases, be sufficient to indicate its true affinity; but it sometimes happens that certain members of a group depart in their structure so widely from the characters of the type to which they belong, that without some other evidence of their affinities no one would think of assigning them to it. This evidence is afforded by development.

An example or two will serve to make the subject clear; and we shall first take one from a case where, without a knowledge of anatomical structure, we should easily go astray in our attempts to assign to the forms under examination their true place in the classification.

If we search our coasts at low water we shall be sure to meet with certain plant-like animals spreading over the rocks or rooted to the fronds of sea-weeds, all of which present so close a resemblance to one another as to have led to their being brought together by the zoologists of a few years ago into a single group, to which, under the name of "Polypes," a definite place was assigned in the classification of the animal kingdom. They are all composite animals, consisting of an association of buds or zooids which remain organically united to one another and give to the whole assemblage the appearance, in many cases, of a little branching tree. Every bud carries a delicate transparent cup, within which is contained the principal part of the animal, and from which this has the power of spontaneously protruding itself; and when thus protruded it will be seen to present a beautiful crown of tentacles surrounding a mouth, through which food is taken into a stomach. As long as no danger threatens, the little animal will continue displayed with its beautiful coronal of tentacles expanded; but touch it ever so lightly, and it will instantly close up its tentacles, retract its whole body, and take refuge in the recesses of its protecting cup.

So far, then, there is a complete agreement between the animals which have been thus associated under the designation of Polypes; and in all that concerns their external form no one point can be adduced in opposition to the justice of this association. When, however, we pass below the surface and bring the microscope and dissecting-needle to bear on their internal organization, we find that among the animals thus formed so apparently alike we have two totally distinct types of structure:—that while in one the mouth leads into a simple excavation of the body on which devolves the whole of the functions which represent digestion, in the other there is a complete alimentary tract entirely shut off from the proper cavity of the body and consisting of distinctly differentiated œsophagus, stomach, and intestine; while in the one the muscular system consists of an indistinct layer of fibres intimately united in its whole extent with the body-walls, in the other there are distinctly differentiated free bundles of muscles for the purpose of effecting special motions in the economy of the animal; while in the one no differentiated nervous system can be detected, in the other there is a distinct nervous ganglion with nervous filaments. In fact the two forms are shown, by a study of their anatomical structure, to belong to two entirely different primary divisions

of the animal kingdom; for while the one has a close affinity with the little freshwater Hydra, and is therefore referred to the Hydroida among the sub-kingdom Cœlenterata, the other is referable to the group of the Polyzoa, has its immediate affinities with the Ascidians, and belongs to the great division of the Molluscoida.

We shall next take an example in which the study of development, rather than of anatomy, affords the clue to the true affinities of the organism.

Attached to the abdomen of various crabs may often be seen certain soft fleshy sacs, to which the name of *Sacculina* has been given. They hold their place by means of a branching root-like extension, which penetrates the abdomen of the crab and winds itself round its intestine or dives into its liver, within which its fibres ramify like the roots of a tree.

Now the question at once presents itself, What position in the animal kingdom are we to assign to this immovably-rooted sac, destitute of mouth and of almost every other organ with which we are in the habit of associating the structure of an animal?

Anatomy will here be powerless in helping us to arrive at a conclusion; for the dissecting-knife shows us little more than a closed sac filled with eggs, and fixed by its tenacious roots in the viscera of its victim. Let us see, however, what we learn from development. If some of the eggs with which the Sacculina is filled be placed in conditions suited to their development, they give origin to a form as different as can well be imagined from the Sacculina. It is an active, somewhat oval-shaped little creature, covered with a broad dorsal shield or carapace, and furnished with two pairs of strong swimming-feet, which carry long bristles, and also with a pair of anterior limbs or antennæ. It is, in fact, identical with a form known to zoologists by the name of "Nauplius," and which has been proved to be one of the young states of the Barnacle and of other lower Crustacea; while even some of the higher Crustacea have been observed to pass through a similar stage.

After a short time the Nauplius of our Sacculina changes its form; the carapace folds down on each side and assumes the shape of a little bivalve shell, while six new pairs of swimming-feet are developed. The little animal continues its active natatory life, and in this stage it is again identical in all essential points with one of the young stages of the Barnacle.

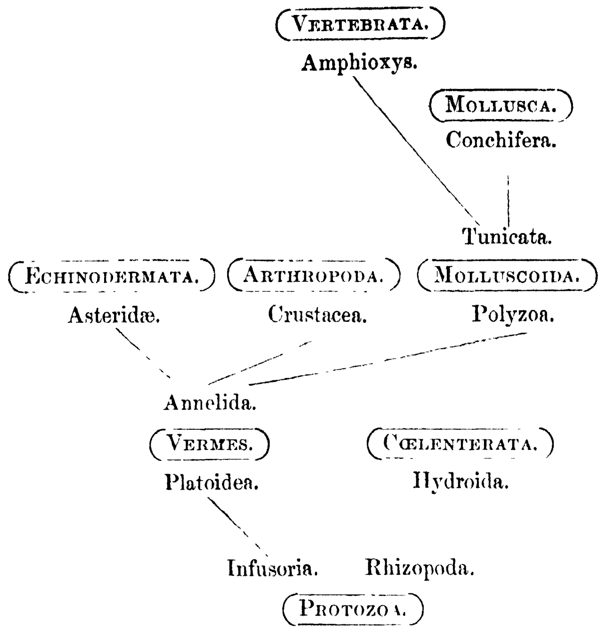
In the mean time a remarkable change takes place in the two antennæ; they become curiously branched and converted into prehensile organs. The young Sacculina now looks out for the crab on which it is to spend parasitically the rest of its life; it loses its bivalve shell; the prehensile antennæ take hold of its victim, and penetrate the soft skin of its abdomen, in order to seek within it the nutriment which is there so plentifully present; locomotion is gone for ever, and the active and symmetrical Nauplius becomes converted into the inert and shapeless Sacculina.

The nearest affinities of Sacculina are thus undoubtedly with the Barnacles, which have been proved, both on anatomical and developmental grounds, to belong to the great division of the Crustacea.

A philosophical classification cannot form a single rectilineal series.

A comparison of animals with one another having thus resulted in establishing their affinities, we may arrange them into groups, some more nearly, others more remotely related to one another. The various degrees and directions of affinity will be expressed in every philosophical arrangement; and as these affinities extend in various directions, it becomes at once apparent that no arrangement of organized beings in a straight line, ascending like the steps of a ladder from lower to higher forms, can give a true idea of the relations of such beings to one another. These relations, on the contrary, can be expressed only by a ramified and complex figure, which we have already compared to that of a genealogical tree.

The following diagram will approximately express the affinities of the leading groups of the animal kingdom:—



Homology.

In the comparison of organized beings with one another, certain relations of great interest and significance become apparent between various organs. These are known by the name of Homologies; and organs are said to be homologous with one another when they can be proved to be constructed on the same fundamental plan, no matter how different they may be in form and in the functions which they may be destined to execute. Organs not constructed on the same fundamental plan may yet execute similar functions; and then, whether they do or do not resemble one another in form, they are said to be merely analogous; and some of the most important steps in modern Biology have resulted from attention to the distinction between Homology and Analogy, a distinction which was entirely disregarded by the earlier schools.

The nature of Homology and its distinction from Analogy will be best understood by a few examples.

Compare the wing of a bird with that of an insect; there is a resemblance between them in external form; there is also an identity of function, both organs being constructed for the purposes of flight: and yet they are in no respect homologous; for they are formed on two distinct plans, which have nothing whatever in common. The relation between them is simply that of analogy.

On the other hand, no finer illustrations of Homology can be adduced than those which are afforded by a comparison with one another of the anterior limbs of the various members of the Vertebrata. Let us compare, for example, the anterior limb of man with the wing of a bird. Here we have two organs between which the ordinary observer would fail to recognize any resemblance—organs, too, whose functions are entirely different, one being formed for prehension, and the other for flight. When, however, they are compared in the light which a philosophic anatomy is capable of throwing on them, we find between the two a parallelism which points to one fundamental type on which they are both constructed.

There is, first, the shoulder-girdle, or system of bones by which in each case the limb is connected with the rest of the skeleton. Now this part of the skeleton in man is very different in form from the same part in the bird; and yet a comparison

of the two shows us that the difference mainly consists in the fact that the coracoid, which in man is a mere process of the scapula, is in the bird developed as an independent bone, and in the further fact that the two clavicles in man are in the bird united into a single V-shaped bone or "furcula." Then, if we compare the arm, forearm, wrist, and hand in the human skeleton with the various parts which follow one another in the same order in the skeleten of the bird's wing, we shall find between the two series a correspondence which the adaptation to special functions may in some regions mask, but never to such an extent as to render the fundamental unity of plan undiscoverable by the method of the higher anatomy. As far as regards the arm and forearm, these in the bird are nearly repetitions of their condition in the human skeleton; but the parts which follow appear at first sight so different in the two cases as to have but little relation to one another; and yet a common type can be traced with great distinctness through the two. Thus the wrist is present in the bird's wing as well as in the anterior limb of man: but while in man it is composed of eight small irregularly shaped bones, arranged in two rows, in the wing it has become greatly modified, the two rows being reduced to one, and the eight bones to two. Lastly, the hand is also represented in the wing, where it constitutes a very important part of the organ of flight, but where it has undergone such great modification as to be recognizable only after a critical comparison; for the five metacarpal bones of the human hand are reduced to two, consolidated with one another at their proximal and distal ends; and then the five fingers of the hand are in the wing reduced to three, which represent the middle finger, fore finger, and thumb. The fore finger in the bird consists of only one phalanx, the middle of two, and the thumb forms a small stylet-like bone springing from the proximal end of the united metacarpals.

In the case now adduced we have an example of the way in which the same organ in two different animals may become very differently modified in form, so as to fit it for the performance of two entirely different functions, and yet retain sufficient conformity to a common plan to indicate a fundamental unity of structure.

Let us take another example: and this I shall adduce from the Vegetable Kingdom, which is full of beautiful instances of the relations with which we are now occupied.

There are the parts known as tendrils, thread-like organs, usually rolling themselves into spirals, and destined, by twining round some fixed support, to sustain climbing plants in their efforts to raise themselves from the ground. We shall take two examples of these beautiful appendages, and endeavour to determine their homological significance.

There is the genus *Smilax*, one species of which adorns the hedges of the south of Europe, where it takes the place of the Bryony and *Tamus* of our English country lanes. From the point where the stalks of its leaves spring from the stem there is given off a pair of tendrils, by means of which the *Smilax* clings to the surrounding vegetation in an inextricable entanglement of flexile branches and bright glossy green foliage.

With the tendrils of the *Smilax* let us compare those of the *Lathyrus aphaca*, a little vetch occasionally met with in waste places and the margins of corn-fields. The leaves are represented by arrow-shaped leaf-like appendages, which are placed opposite to one another in pairs upon the stem; but instead of each of these carrying two tendrils at its origin, like the leaves of the *Smilax*, a single tendril springs from the middle point between every pair.

The tendrils in the two cases, though similar in appearance and in function, differ thus in number and arrangement; and the questions occur:—Are they homologous with one another, or are they only analogous? and if they are only analogous, can we trace between them and any other organ homologous relations?

To enable us to decide this point, we must bear in mind that a leaf, when typically developed, consists of three portions—the lamina or blade, the petiole or leaf-stalk, and a pair of foliaceous appendages or stipules placed at the base of the leaf-stalk. Now this typical leaf affords the key to the homologies of the tendrils in the two cases under examination.

Take the *Smilax*. In this case there are no stipules of the ordinary form; but the two tendrils hold exactly the position of the stipules in our type leaf, and must

be regarded as representing them. We have only to imagine these stipules so modified in their form as to become reduced to two long spiral threads, and we shall at once have the tendrils of the *Smilax*. On the other hand, let the stipules in our type remain as leaf-like organs, and let the rest of the leaf (the lamina and petiole) lose its normal character and become changed into a spiral thread, and we shall then have the stipules of our type leaf retained in the two opposite leaf-like organs of the *Lathyrus*, while the remainder of the type leaf will present itself in the condition of the *Lathyrus*-tendril which springs from the central point between them.

The tendrils of the *Smilax* and of the *Lathyrus aphaca* are thus not homologous with one another, but only analogous; while those of the *Smilax* are homologous with a pair of stipules, and those of the *Lathyrus* homologous with the lamina and petiole of a leaf.

Besides the homology discoverable between the organs of different animals and plants, a similar relation can be traced between organs in the same animal or plant, as, for example, that between the different segments of the vertebral column (which can be shown to repeat one another homologically), and that between the parts composing the various verticils of the flower and leaves in the plant.

The existence of homological relations such as have been just illustrated admits of an easy explanation by the application of the doctrine of Descent, according to which the two organs compared would originate from a common ancestral form. In accordance with this hypothesis, Homology would mean an identity of genesis in two organs, as Analogy would mean an identity of function.

Distribution and Evolution.

Another very important department of biological science is that of the distribution of organized beings. This may be either Distribution in Space (Geographical Distribution) or Distribution in Time (Palæontological Distribution). Both of these have of late years acquired increased significance; for we have begun to get more distinct glimpses of the laws by which they are controlled, of the origin of Faunas and Floras, and of the causes which regulate the sequence of life upon the earth. Time, however, will not allow to enter upon this subject as fully as its interest and importance would deserve; and a few words on palæontological distribution is all that I can now venture on.

The distribution of organized beings in time has lately come before us in a new light, by the application to it of the hypothesis of Evolution. According to this hypothesis, the higher groups of organized beings now existing on the earth's surface have come down to us, with gradually increasing complexity of structure, by a continuous descent from forms of extreme simplicity which constituted the earliest life of our planet.

In almost every group of the animal kingdom the members which compose it admit of being arranged in a continuous series, passing down from more specialized or higher to more generalized or lower forms; and if we have any record of extinct members of the group, the series may be carried on through these. Now, while the Descent hypothesis obliges us to regard the various terms of the series as descended from one another, the most generalized forms will be found among the extinct ones; and the further back in time we go the simpler do the forms become.

By a comparison of the forms so arranged we obtain, as it were, the law of the series, and can thus form a conception of the missing terms, and continue the series backwards through time, even where no record of the lost forms can be found, until from simpler to still simpler terms we at last arrive at the conception of a term so generalized that we may regard it as the primordial stock, the ancestral form from which all the others have been derived by descent.

This root form is thus not actually observed, but is rather obtained by a process of deduction, and is therefore hypothetical. We shall strengthen, however, its claims to acceptance by the application of another principle. The study of Embryology shows that the higher animals, in the course of their development, pass through transitory phases which have much in common with the permanent condition of lower members of the type to which they belong, and therefore with its

extinct representatives. We are thus enabled to lay down the further principle, that the individual, in the course of its own development from the egg to the fully formed state, recapitulates within that short period of time the various forms which its ancestry presented in consecutive epochs of the world's history; so that if we knew all the stages of its individual development, we should have a key to the long line of its descent. Through the hypothesis of Evolution, palæontology and embryology are thus brought into mutual bearing on one another.

Let us take an example in which these two principles seem to be illustrated. In rocks of the Silurian age there exist in great profusion the remarkable fossils known as Graptolites. These consist of a series of little cups or cells arranged along the sides a common tube; and the whole fossil presents so close a resemblance to one of the Sertularian hydroids which inhabit the waters of our present seas as to justify the suspicion that the Graptolites constitute an ancient and long since extinct group of the Hydroida. It is not, however, with the proper cells, or hydrothecæ, of the Sertularians that the cells of the Graptolite most closely agree, but rather with the little receptacles which in certain Sertularinæ belonging to the family of the Plumularidæ we find associated with the hydrothecæ, and which are known as "nematophores." A comparison of structure, then, shows that the Graptolite may, with considerable probability, be regarded as representing a Plumularia in which the hydrothecæ had never been developed, and in which their place had been taken by the nematophores.

Now it can be shown that the nematophores of the living Plumularidæ are filled with masses of protoplasm which have the power of throwing out pseudopodia, or long processes of their substance, and that they thus resemble the Rhizopoda, whose soft parts consist entirely of a similar protoplasm, and which stand among the Protozoa, or lowest group of the animal kingdom. If we suppose the hydrothecæ suppressed in a Plumularian, we should thus nearly convert it into a colony of Rhizopoda, from which it would differ only in the somewhat higher morphological differentiation of its cœnosarc, or common living bond by which the individuals of the colony are organically connected. And just such a colony would, under this view, a Graptolite be, waiting only for the development of hydrothecæ to raise it into the condition of a Plumularian.

Bringing, now, the Evolution hypothesis to bear upon the question, it would follow that the Graptolite may be viewed as an ancestral form of the Sertularian hydroids, a form having the most intimate relations with the Rhizopoda, that hydranths and hydrothecæ became developed in its descendants, and that the Rhizopodal Graptolite became thus converted in the lapse of ages into the hydroidal Sertularian.

This hypothesis would be strengthened if we found it agreeing with the phenomena of individual development. Now such Plumularidæ as have been followed in their development from the egg to the adult state do actually present well-developed metamorphoses before they show a trace of hydrothecæ, thus passing in the course of their embryological development through the condition of a Graptolite, and recapitulating within a few days stages which it took incalculable ages to bring about in the palæontological development of the tribe.

I have thus dwelt at some length on the doctrine of Evolution because it has given a new direction to biological study, and must powerfully influence all future researches. Evolution is the highest expression of the fundamental principles established by Mr. Darwin, and depends on the two admitted faculties of living beings—*heredity*, or the transmission of characters from the parent to the offspring, and *adaptivity*, or the capacity of having these characters more or less modified in the offspring by external agencies or, it may be, by spontaneous tendency to variation.

The hypothesis of Evolution may not, it is true, be yet established on so sure a basis as to command instantaneous acceptance; and for a generalization of such vast significance no one can be blamed in demanding a broad and indisputable foundation of facts. Whether, however, we do or do not accept it as a necessary deduction from established facts, it is at all events certain that it embraces a greater number of phenomena and suggests a more satisfactory explanation of them than any other hypothesis which has yet been proposed.

With all our admiration, however, for the doctrine of Evolution, as one of the most fertile and comprehensive of philosophic hypotheses, we cannot shut our eyes to the difficulties which lie in the way of accepting it to the full extent which has been sometimes claimed for it. It must be borne in mind that though among some of the higher Vertebrata we can trace back for some distance in geological time a continuous series of forms which may safely be regarded as derived from one another by gradual modification (as has been done, for example, so successfully by Prof. Huxley in the case of the Horse), yet the instances are very few in which such a sequence has been actually established; while the first appearance on the earth's crust of the various classes presents itself in forms which by no means belong to the lowest or most generalized of their living representatives. On this fact, however, I do not lay much stress; for it will admit of explanation by referring it to the deficiency of the geological record, and then demanding a lapse of time (of enormous length, it is true) during which the necessary modifications would be in progress before the earliest phase of which we have any knowledge could have been reached.

Again, we must not lose sight of the hypothetical nature of those primordial forms in which we regard the branches of our genealogical tree as taking their origin; and while the doctrine of the recapitulation of ancestral forms has much probability, and harmonizes with the other aspects of the Evolution doctrine into a beautifully symmetrical system, it is one for which a sufficient number of actually observed facts have not yet been adduced to remove it altogether from the region of hypothesis.

Even the case of the Graptolites already adduced is an illustration rather than a proof; for the difficulty of determining the true nature of such obscure fossils is so great, that we may be altogether mistaken in our views of their structure and affinities.

To me, however, one of the chief difficulties in the way of the doctrine of evolution, when carried to the extreme length for which some of its advocates contend, appears to be the unbroken continuity of inherited life which it necessarily requires through a period of time whose vastness is such that the mind of man is utterly incapable of comprehending it. Vast periods, it is true, are necessary in order to render the phenomena of evolution possible; but the vastness which the antiquity of life, as shown by its remains in the oldest fossiliferous strata, requires us to give to these periods may be even greater than is compatible with continuity.

We have no reason to suppose that the reproductive faculty in organized beings is endowed with unlimited power of extension; and yet, to go no further back than the Silurian period (though the seas which bore the Eozoon were probably as far anterior to those of the Silurian as these are anterior to our own), the hypothesis of evolution, when carried to the extreme length of which it seems susceptible, requires that in that same Silurian period the ancestors of the present living forms must have existed, and that their life had continued by inheritance through all the ramifications of a single genealogical tree down to our own time—the branches of the tree, it is true, here and there falling away, with the extinction of whole genera and families and tribes, but still some always remaining to carry on the life of the base through a period of time to all intents and purposes infinite. It is true that in a few cases a continuous series of forms, regularly passing from lower to higher degrees of specialization, and very probably connected with one another by direct descent, may be followed through long geological periods—as, for example, the graduated series, already alluded to, which may be traced between certain mammals of the Eocene and others living in our own time, as well as the very low forms which have come down to us, apparently unmodified, from the epoch of the Chalk; but incalculably great as are these periods, they are but as the swing of the pendulum in a millennium, when compared with the time which has elapsed since the first animalization of our globe.

Is the faculty of reproduction so wonderfully tenacious as all this, that through periods of inconceivable duration, and exposed to influences the most intense and the most varied, it has still come down to us in an unbroken stream? Have the strongest, which had survived in the struggle for existence, necessarily handed down to the strongest which should follow them the power of continuing, as a per-

petual heirloom, the life which they had themselves inherited? Or have there been many total extinctions and many renewals of life—a succession of genealogical trees, the earlier ones becoming old and decayed and dying out, and their place taken by new ones which have no kinship with the others? Or, finally, is the doctrine of evolution only a working hypothesis, which, like certain algebraic fictions, may yet be of inestimable value as an instrument of research? For as the higher calculus becomes to the physical inquirer a power by which he unfolds the laws of the inorganic world, so may the hypothesis of evolution, though only an hypothesis, furnish the biologist with a key to the order and hidden forces of the world of life; and what Leibnitz, and Newton, and Hamilton have been to the physicist, is it not that which Darwin has been to the biologist?

But even accepting as a great truth the doctrine of evolution, let us not attribute to it more than it can justly claim. No valid evidence has yet been adduced to lead us to believe that inorganic matter has become transformed into living otherwise than through the agency of a preexisting organism; and there remains a residual phenomenon still entirely unaccounted for. No physical hypothesis, founded on any indisputable fact, has yet explained the origin of the primordial protoplasm, and, above all, of its marvellous properties, which render evolution possible.

Accepting, then, the doctrine of evolution in all freedom, and with all its legitimate consequences, there remains, I say, a great residuum unexplained by physical theories. Natural selection, the struggle for existence, the survival of the fittest, will explain much, but they will not explain all. They may offer a beautiful and convincing theory of the present order and fitness of the organic universe, as the laws of attraction do of the inorganic; but the properties with which the primordial protoplasm is endowed (its heredity and its adaptivity) remain unexplained by them; for these properties are their cause, and not their effect.

For the cause of this cause we have sought in vain among the physical forces which surround us, until we are at last compelled to rest upon an independent volition, a far-seeing intelligent design. Science may yet discover, even among the laws of physics, the cause it looks for; it may be that even now we have glimpses of it—that those forces among which recent physical research has demonstrated so grand a unity (light, heat, electricity, magnetism), when manifesting themselves through the organizable protoplasm, become converted into the phenomena of life—and that the poet has unconsciously enunciated a great scientific truth when he tells us of

> "Gay lizards glittering on the walls
> Of ruined shrines, busy and bright,
> As though they were *alive with light*."

But all this is only carrying us one step back in the grand generalization. All science is but the intercalation of causes, each more comprehensive than that which it endeavours to explain, between the great primal cause and the ultimate effect.

I have thus endeavoured to sketch for you, in a few broad outlines, the leading aspects of biological science, and to indicate the directions which biological studies must take. Our science is one of grand and solemn import; for it embraces man himself, and is the exponent of the laws which he must obey. Its subject is vast; for it is life, and life stretches back into the illimitable past, and forward into the illimitable future. Life, too, is everywhere. Over all this wide earth of ours, from the equator to the poles, there is scarcely a spot which has not its animal or its vegetable denizens—dwellers on the mountain and on the plain, in the lake and on the prairie, in the arid desert and the swampy fen—from the tropical forest, with its strange forms and gorgeous colours and myriad voices, to the ice-fields of polar latitudes and those silent seas which lie beneath them, where living things unknown to warmer climes congregate in unimaginable multitudes. There is life all over the solid earth; there is life throughout the vast ocean, from its surface down to its great depths, deeper still than the lead of sounding-line has reached.

And it is with these living hosts, unbounded in their variety, infinite in their numbers, that the student of biology must make himself acquainted. It is no light

task which lies before him—no mere pastime on which he may enter with trivial purpose, as though it were but the amusement of an hour; it is a great and solemn mission, to which he must devote himself with earnest mind and with loving heart, remembering the noble words of Bacon:—

"Knowledge is not a couch whereon to rest a searching and restless spirit; nor a terrace for a wandering and variable mind to walk up and down with a fair prospect; nor a tower of state for a proud mind to raise itself upon; nor a fort or commanding ground for strife and contention; nor a shop for profit and sale; but a rich storehouse for the glory of the Creator and the relief of man's estate."

Botany.

On Parasitic Algæ. By W. Archer.

On a Tree-Aloe from South-East Africa. By T. Baines.

On the Plants collected in Bermuda by Mr. H. N. Moseley. *By* Professor Thiselton Dyer, *B.A.*

On the Crystals in the Testa and Pericarp of certain Plants. By* Professor Gulliver, *F.R.S.*

The author, remarking how much microscopists have of late been interested by the diverse appearances on the surface of certain seeds, expresses his opinion that the value of observations of this kind might be much increased if they were carried a little deeper into the texture of the seed-coat and pericarp. In one or other of these parts he finds short prismatic crystals, apparently of oxalate of lime, constantly present in many plants, and as constantly absent from the same parts of other plants; and, as regards the frequent and true remark that such crystals occur in numberless plants, he submits that this is no answer to the rational question as to the orders or species which are or are not characterized by certain saline crystals in the testa or other part of the plant. Illustrative drawings were exhibited of the crystals in *Geranium* and *Ribes*; and of the crystals in *Ulmus* and Compositæ engravings had been published in the 'Quarterly Journal of Microscopical Science,' July 1873, and 'Science Gossip,' May 1873. In the present paper he describes the crystals in Tiliaceæ, Aceraceæ, Geraniaceæ, Grossulariaceæ, Compositæ, Primulaceæ, and Dioscoreaceæ.

The crystals occur regularly studded in plainly defined cells and, though, very variable in size, have an average diameter of about $\frac{1}{2900}$ of an inch, and in form are square, oblong, lozenge-shaped, commonly belong to one or other of the prismatic systems, but often are merely granular or otherwise irregular like certain starch-granules, though easily distinguishable therefrom by the iodine test. The author, in conclusion, expressed the hope that both neophytes and experts would pay more attention to this branch of phytotomy, especially as such observations, and the minute structure of plants generally, have been and still are sadly neglected in even the most comprehensive books of descriptive botany and micrography.

On the Mosses of the West Riding of Yorkshire. By Charles P. Hobkirk, *President of Huddersfield Naturalists' Society*†.

The list of West-Riding Mosses at the end of this paper, numbering nearly 300, chiefly made up from the author's own observations and those of his friends, was

* Printed *in extenso* with additions and a plate in the 'Monthly Microscopical Journal' for December 1873.

† Published *in extenso* in the 'Journal of Botany,' New Series, vol. ii. p. 327 *et seq.*

prefaced by a short introduction, descriptive of the principal geological features of the district. He then showed the course of the various riversheds, and the work which has been done in each. The Wharfe, Upper Aire, and Calder are the best worked for mosses, the others having been scarcely touched upon yet.

Many rarities have already been found; and when the other more southern districts have been thoroughly examined, the author was of opinion that the list of Mosses would be largely increased. He then described a few of the principal new and rarer species, and concluded by recommending the West-Riding botanists to direct their studies to the Mosses.

On the Subalpine Vegetation of Kilimanjaro, E. Africa *. *By* Dr. J. D. Hooker, *C.B.*, *F.R.S.*

Remarks on Plants collected by the Voyager Dampier. *By* Professor Lawson, *M.A.*

On a Course of Practical Instruction in Botany. *By* Professor Lawson, *M.A.*

On the Vegetation of Bermuda. *By* H. N. Moseley.

On some of the Changes going on in the South-African Vegetation through the Introduction of the Merino Sheep. *By* John Shaw.

The author commenced by referring to the fact that civilization and Merino sheep had introduced one obnoxious plant (the *Xanthium spinosum*) into the sheep-walks of South Africa. As its achenes get into the wool and seriously injure its value, the Government have legislated for its compulsory destruction. In the Orange-River Free State, where there was no legislation on the weed until lately, wool had become so filled with these that its value was deteriorated nearly 50 per cent. Sheep also, in consequence of the overstocking of farms in the inland districts of the Cape, are doing very serious injury directly by eating down the better and more agreeable plants, giving range to poisonous and bitter ones, and even so changing the climate as to make the country better suited to the plants of the neighbouring regions, which march into the sheep-walks to aid the sheep in thrusting out and extirpating the indigenous flora.

After sketching the distribution of plants in South Africa, the author went on to particularize the character of the prairie-like midlands of the Cape, with their luxuriant grass and vegetation. Since sheep have been introduced the grass has fast disappeared, the ground (by the hurried march of the sheep for food amongst a scattered bush) has become beaten and hardened, and the seasonable rains which do come are accordingly allowed to run off the surface without soaking into the ground to the extent formerly the case. The country is thus drying up, the fountains becoming smaller and smaller, and the prospect is very clear that the midland regions will turn into a semi-desert. Indeed the plants of the singular regions known as the Karoo, in the south-west of the Cape (which from its position is locked in to the north and south by mountains, and is favoured little by rain), are travelling northwards rapidly and occupying this now similar dry tract of country. The herbage is essentially a Karoo one already. It contains most prominently Karoo plants, such as the *Chrysocomas* and the *Elytropappi*.

The author further referred to the great increase of poisonous and bitter herbage. It is dangerous to have stock in many farms, which formerly were free from any injurious herbs. Long stretches of the colony are abundantly occupied by *Melicæ*, which are eaten by the oxen and cause intoxication, to the serious hindrance of transport.

* Printed *in extenso* in the Journal of the Linnean Society.

On Fern-stems and Petioles of the Coal-measures. *By* Professor W. C. Williamson, *F.R.S.*

The author described the structure of several stems of *Calamites* and Lycopodiaceous plants from the Coal-measures, in which a thick vascular zone intervened between a central pith and an outer bark, and which zone increased in thickness by successive additions made to its external surface through the genetic agency of the innermost layer of the bark. Adopting these plants as typical representatives of a condition wholly unknown amongst living Cryptogams, he called attention to a series of stems from the Coal-measures which bore the appearance of being the petioles and rhizomes of ferns. One of these, to which he had previously assigned the provisional name of *Edraxylon*, he now showed to be an undoubted fern, since he has obtained it with leaflets attached to it. This plant proves to be one of the species of *Pecopteris* in which the rachis and petiole is covered with minute tubercles, as in some recent Cyatheas. After examining a series of other stems, including the *Stauropteris* of Binney and the *Zygopteris Lacatti* recently described by M. Renault, he examined the *Palmacites carbonigenus* of Corda, and which latter has generally been regarded as a palm. The author rejected this view, and came to the conclusion that the plant was a fern allied to the Marattiaceæ of the present day. In none of the above plants was the slightest trace of the exogenous growth so common amongst the Lycopods and Calamites to be found. But the author thought it probable that the *Heterangium Grievii*, recently described by himself in a memoir now being printed by the Royal Society, and in which a very feeble attempt at the development of such a growth was observable, might prove to be a fern. But even in that case the instance was such an isolated one, so far as our present knowledge extends, and the growth was so feebly developed, that it merely appeared like one of those exceptions which prove the rule. It only indicated the absence in nature of those sharply defined boundary lines which the systematist is ever seeking to establish, but within which nature refuses to be restrained.

On the Flora of the Environs of Bradford. *By* Dr. Willis.

Zoology.

On some Recent Results with the Towing-net on the South Coast of Ireland. *By* Professor Allman, *F.R.S.*

1. *Mitraria.*

Only a single specimen was obtained of the little *Mitraria* which formed the subject of the present communication; and neither its structure nor development was made out as completely as could have been wished. From the Mediterranean species described in a former communication (British Association Report for 1872), it differs in some points of structure and in the mode of annulation of the developing worm. It possesses the usual *Mitraria*-form—that of a hemispherical dome, having its base encircled by a band of long vibratile cilia. In the side of the dome, a little above the ciliated band, is the mouth, which leads into a rather wide pharynx clothed with a ciliated epithelium. The pharynx runs through the dome parallel to its base, and opens into a capacious stomach, which continues in the same direction until it joins the intestine. This then turns down abruptly at right angles to the previous portion of the alimentary canal, and then projects for a short distance beyond the base of the dome, carrying with it, hernia-like, the walls of the base.

The true body-walls of the future worm, of which the *Mitraria* is the larva, seem as yet confined to the intestinal segment of the alimentary canal. They already present the commencement of annulation, which, however, exists only on the dorsal and ventral sides; while two broad bands of very distinct fibres may be seen,

one on the right and the other on the left side, extending transversely from the dorsal to the ventral surface.

The ciliated band which runs round the base of the dome possesses a rather complex structure. It consists of two concentric rings—an outer one composed of large, oval, distinctly nucleated cells; and an inner one of a granular structure and yellowish colour, in which no distinct cells could be demonstrated. The cilia form two concentric wreaths borne by the underside of the band—an outer wreath consisting of very long cilia, and borne by the inner edge of the outer portion of the band; and an inner wreath of much shorter cilia, borne by the inner edge of the inner portion. The band, with its cilia, is interrupted for a very short space at the aboral side of the dome. There is probably at this spot an entrance into a water-vascular system. No such system, however, was observed in the specimen, though the author had described in another species of *Mitraria* a system of sinuses which appear to exist in the walls of the dome, and which he regarded as representing a water-vascular system (Brit. Assoc. Report for 1872).

Occupying the very summit of the dome is a large, somewhat quadrilateral ganglion, from which two distinct filaments are sent down, one on each side of the alimentary canal; but he was not able to follow these filaments to their destination. The bilateral symmetry of the ganglion suggests its formation out of two lateral halves. Though its very superficial position gives it the appearance of being a mere thickening of the walls, the view here taken of its being a nervous ganglion seems to be the only one consistent with its relations to the surrounding parts.

On each side of the pharynx, a little behind the mouth, is a small oval ganglion-like body, from which a filament runs to the ciliated band. Some delicate filaments may also be seen lying between the pharynx and the walls of the dome on which they seem to be distributed; but the author could not trace them to any distinct ganglionic centre.

The great apical ganglion carries two very obvious black ocelliform spots, and, besides these, two clear vesicles enclosing each a clear spherical corpuscle. The two vesicles may probably be regarded as auditory capsules.

The further development of this larval form has not been observed. It probably consists chiefly in the continued prolongation of the alimentary canal beyond the base of the hemispherical dome, the completion of the annulation by its extension to the right and left sides, and the gradual contraction of the dome and final absorption of the ciliated band.

2. *Tornaria.*

Two specimens of the larval form originally discovered by Johann Müller, and described by him under the name of *Tornaria*, were obtained; but these unfortunately perished before a sufficiently exhaustive examination of them could be made. On the whole, their structure agrees closely with what has been pointed out by Alex. Agassiz, in his valuable and elaborate memoir on *Tornaria* and *Balanoglossus*. The species appears to be different from those hitherto described. The gills had not begun to show themselves, and there were but traces of the "lappets" described in other species as appended to the posterior extremity of the stomach.

The author believed that he could distinguish a minute ganglion on each side of the œsophagus; filaments were sent off from it to the neighbouring parts, and the two were connected to one another by a subœsophageal commissure. The water-vascular chamber was very distinct, but the so-called heart was not observed; while within the body-cavity, lying close to the dorsal pore and over the canal by which the great water-sac communicates with the external medium, was a small, closed, rather thick-walled vesicle, containing numerous oval corpuscles. Of the nature of this vesicle the author could not offer any opinion.

The cushion-like body which occupies the summit of the larva, exactly as in *Mitraria*, and supports the two ocelliform spots, was very distinct; and so also was the contractile chord which extends from this to the walls of the water-sac. The author, however, could not here, any more than in *Mitraria*, regard the cushion-like body as a mere thickening of the walls; he believed it to be a nerve-mass, and

thought he could trace two fine filaments proceeding from it and running down, one towards the right and the other towards the left side of the alimentary canal; but he was not able to follow them for any distance, and he does not regard their existence as confirmed. The extremely superficial situation of this body, which makes it resemble a mere thickness of the walls, is paralleled by that of the great ventral nerve-mass in *Sagitta*.

The contractile chord which runs to the water-sac is probably attached to a capsular covering of the ganglion, rather than directly to the ganglion itself. This chord, though showing strong contractions by which the summit of the larva is drawn down towards the water-sac, is of a homogeneous structure, presenting no appearance of distinct fibrillæ or of other contractile elements.

The author instituted a comparison between *Tornaria* and *Mitraria*. We have in both the external transparent pyramidal or dome-shaped body, with a lateral oral orifice and a basal anal orifice, enclosing an alimentary canal which is divisible into three regions, and takes a partly horizontal and partly vertical direction in its course from one orifice to the other*; we have in both, near the base of the body, the circular band which carries long vibratile cilia, accompanied by a row of pigment spots, and in both the cushion-like ganglion-carrying ocelli.

From *Mitraria*, *Tornaria* chiefly differs in the presence of the thick sinuous and convoluted bands which give it so close a resemblance to certain Echinoderm larvæ, and which are entirely absent from *Mitraria*, and in its water-vascular system, with the contractile chord which extends from this to the apical ganglion. If a water-vascular system is present in *Mitraria*, it consists there of a system of sinuses excavated in the walls of the dome, but without any representative of the great central sac. In *Mitraria* the great apical ganglion carries not only the two ocelli, but also two capsules, probably auditory; these capsules do not exist in *Tornaria*. In *Mitraria* the two nerve-chords which the apical ganglion sends down one on each side of the alimentary canal are very distinct; in *Tornaria*, if they exist at all, they are by no means obvious. Finally, the ciliary circlet is simple in *Tornaria*, while in *Mitraria* it is double.

According to Alexander Agassiz's account of the development of *Tornaria* into *Balanoglossus*, the great transverse circlet of cilia becomes, by the elongation of the body, gradually pushed backwards, so as to form the anal ciliated ring of the young worm. In *Mitraria* the great ciliary circlet remains unchanged in position, and is probably ultimately absorbed, the worm during its development acquiring a new anal wreath of cilia.

3. *Ametrangia hemisphærica* (nov. gen. et sp.).

Among the most abundant products of the towing-net was a little hydroid Medusa, remarkable for the want of symmetry in the distribution of its gastro-vascular canals. It is of a hemispherical form, with the base about half an inch in diameter, and provided with very numerous (more than 100) marginal tentacles, which are very extensile, and may at one time be seen floating to a length of three or four inches, and at another coiled into a close spiral against the margin of the umbrella. Each tentacle originates in a bulbous base with a distinct ocellus. No lithocysts are visible on the margin. The velum is of moderate width.

The manubrium forms a small projection from the summit of the umbrella, and terminates in four rather indistinct lips. From the base of the manubrium three rather wide offsets are sent off at equal intervals into the walls of the umbrella. These gradually contract in diameter, and then, as three narrow tubes of uniform diameter, run towards the margin, where they open into the circular canal. The symmetry of the radiating canals is confined to these three primary trunks. From their wide proximal ends each sends off branches, some of which may be traced to the margin, where, like the three primary canals, they enter the circular canal; while others can be followed for various distances in the umbrella-walls, in which they terminate by blind extremities without ever reaching the margin. These branches are very irregular in the number sent off from each primary canal as well as in their length and directions.

* In the species of *Mitraria* described by J. Müller and by Mecznikoff, both oral and anal orifices are basal, and the alimentary canal presents a U-shaped curvature.

The generative elements are formed in oval sporosacs, developed one on each of the three primary canals at the spot where the wider base passes into its narrower continuation. The ova may be seen within them in various stages of development; they increase considerably in size before the commencement of segmentation, always showing up to that period a large and distinct germinal vesicle with germinal spot, and with a distinct nucleolus in the interior of the germinal spot. The development of the ovum proceeds within the sporosac to the segmentation of the vitellus and the formation of the planula, which now breaks through the outer walls of the sporosac and remains for some time adhering to their external surface. The planula differs remarkably from the typical hydroid planula. It remains of a nearly spherical form, never acquiring cilia, and possesses little or no power of locomotion. The gastric cavity, however, is fully formed. The author was unable to follow the ova in their further development.

The little Medusa now described departs in several important points from the typical hydroid Medusa. From this it differs in the ternary disposition of the primary radiating canals, and in the irregular non-symmetrical arrangement of those which are subsequently formed. Among the very many specimens examined, the author never found any in which the canals had become regular in their disposition, even in those which had discharged the contents of their sporosacs, and had evidently attained the term of their existence. It differs also from the typical Medusa in the form and non-ciliated condition of the planula; and still further in the fact that while the generative elements are borne on sporosacs, developed on the radiating canals, the marginal bodies are ocelli and not lithocysts.

4. *Circe invertens* (nov. sp.).

Among the hydroid Medusæ captured in the towing-net were two or three specimens of a species referable to the genus *Circe* of Mertens. It measures about half an inch in its vertical diameter and about a quarter of an inch transversely. It is cylindrical from its base upwards for about two thirds of its height, and then contracts abruptly and arches dome-like towards the truncated summit, which is surmounted by a solid cone of the gelatinous umbrella substance. From the summit of the umbrella-cavity, a solid somewhat fusiform extension of the roof hangs down in the axis of its cavity for about two thirds of its depth, and at its free end carries the manubrium, which extends nearly to the codonostome. The margin of the umbrella carried eighty very short and but slightly extensile tentacles, which were connected at their bases by a very narrow membranous extension of the margin, with rather irregular free edge. Lithocysts are situated at irregular intervals upon the margin. There are about sixteen of them; they consist each of a minute spherical vesicle with a single large spherical concretion. There are no ocelli. There is a moderately wide velum.

The radiating canals are eight in number. They spring from the base of the manubrium, run up the sides of the solid process which hangs from the summit of the umbrella, pass from this to the walls of the umbrella, and then run down towards the margin in order to open into the circular canal.

The generative elements are borne in pendent sporosacs, which spring from the radiating canals close to the summit of the umbrella-cavity.

The motion of the Medusa takes place by means of sudden jerks, reminding us of the way in which certain Diphyidæ dart through the water.

The Medusa possesses also a very singular habit of partial inversion. This takes place along the line which separates the dome-like portion of the umbrella-cavity from the lower cylindrical portion, and consists in the withdrawal of this dome-like summit and the lower portion of the cavity. When thus inverted, the little animal presents a drum-shaped form, with the manubrium hanging far out of the codonostome.

Alexander Agassiz considers the genus *Circe* of Mertens synonymous with *Trachynema*, Gegenbaur, and points out that the name of *Circe* has been already used for a genus of Mollusca. He further removes it from among the true hydroid Medusæ, and, regarding it as closely allied to the *Æginidæ*, places it along with those in the *Haplostomæ*, Agassiz, a suborder of the *Discophora*.

The author, however, could not see sufficient grounds for the removal of Mertens's genus from the true *Hydroida*, with which the Medusa now described agrees in all essential points, including the form and disposition of the gastrovascular and generative systems and the structure of the marginal lithocysts. Neither could he agree with Alexander Agassiz in identifying it with *Trachynema*. The greatly developed solid peduncle by which the manubrium in *Circe* is suspended from the summit of the umbrella-cavity (in a way, however, which has its parallel in *Tima* among others), is of itself a character of generic importance by which *Circe* must be kept apart from *Trachynema*. It is true that Gegenbaur's *Trachynema* has the character of a young form; and until we have further evidence of its adult state its affinities cannot be regarded as established.

Gegenbaur believes that he has established the direct development of *Trachynema* from the egg without the intervention of a hydriform trophosome; but unfortunately we have no data by which to compare in this respect *Circe* with *Trachynema*.

It must be admitted, too, that in the imperfect contractility of the marginal tentacles and in the somewhat greater firmness of the umbrella-walls the little medusa described in the present communication possesses characters which look towards the *Æginidæ*; but these are by no means sufficiently strong to justify its separation from the ordinary hydroid Medusæ.

5. *Tomopteris.*

A few young specimens of this beautiful little worm were obtained; and the author was enabled to confirm the statements of Grube and of Keferstein, who describe in it a double ventral nerve-chord, though other observers have failed to discover this part of the nervous system, and throw doubt upon its existence. In adult specimens examined some years previously by the author no ventral chord could be detected.

The ventral portion of the nervous system consists of two flat ribbon-shaped chords, which are given off from the inferior side of the nerve-ring which surrounds the pharynx just behind the mouth. These run parallel to one another, separated by a narrow interval; they lie on the ventral walls of the animal, and may be traced through the narrow tail-like termination of the body as far as its extremity. They present no ganglionic swellings; but opposite to every pair of feet each sends off a filament which passes to the foot of its own side, in which it is distributed.

Dr. Anton Dohrn has just informed the author that he, too, has distinctly seen the ventral chord of *Tomopteris*.

On the Distribution of the Antelopes in Southern and Western Asia. By W. T. Blanford.

On the Fauna of Persia. By W. T. Blanford, *F.G.S., C.M.Z.S.*

Persia being situated on the limit of the region occupied by the Palæarctic fauna, presents in different parts of the country several peculiarities, in consequence of types belonging to the Indian and desert faunæ being largely intermixed with each other, and with those peculiar to the Palæarctic province.

In the extreme north the animals are identical with those of the neighbouring parts of Europe and Asia, the steppe fauna of Southern Russia being met with in the open parts of the country; whilst the dense forests of the shores of the Caspian are chiefly inhabited by the same animals as occur in the woods of South-eastern Europe and Asia Minor, mixed, however, with a few Asiatic types, as the tiger, the common pheasant, and a crotaline snake (*Halys*). Throughout the greater portion of the Persian territory the fauna is of the desert type, marked by the prevalence of such forms as *Equus hemionus*, *Gazella*, *Gerbillus*, *Buteo ferox*, *Gyps fulvus*, *Bucanetes githagineus*, *Pterocles*, and *Houbara*, *Eremias*, *Psammophis*, *Eryx*, &c.; whilst in the south the purely Palæarctic forms either disappear entirely, or are represented by winter migrants only, and several Indian forms make their appearance, e. g. *Gazella*

bennetti, Sciurus palmarum, Athene brama, Coracias indica, Pratincola caprata, Passer (Gymnoris) flavicollis, P. indicus, Ortygornis pondiceriana, Acanthodactylus cantoris, and *Calotes versicolor*. Several of these extend as far west as the head of the Persian Gulf, but they rarely occur above elevations of 3000 feet above the sea. With the above are associated some animals hitherto only found in Baluchistan and Sind, and a few forms previously only known from North-eastern Africa or Arabia. The whole of Persia may thus be divided into three principal regions,—the forest countries of Ghilan and Mazendaran on the Caspian, and probably the wooded slopes on the eastern border of Mesopotamia, extending south to the neighbourhood of Shiráz, the fauna of which is essentially European; the plateau of Persia, which is occupied by a mixture of Palæarctic and desert forms; and Southern Persia with Baluchistan, inhabited chiefly by Indian and desert types.

Some Remarks on the Mollusca of the Mediterranean.
By J. Gwyn Jeffreys, *F.R.S.*

After noticing the numerous writers on this subject, from Aristotle to modern authors, Mr. Jeffreys remarked that the Mediterranean had long been debatable ground with respect to the division of the European seas into zoological provinces. He referred to 'The Natural History of the European Seas,' by the late Professor Edward Forbes and Mr. Godwin-Austen, and said that he agreed with the latter in his view that the Mediterranean is "a vast lateral expansion of the Atlantic," and not only in its physical aspects, but in most of its natural-history productions; and he believed that the missing links would sooner or later be discovered. The newest and most complete list of the Testaceous Mollusca of the Mediterranean is that by the Marquis de Monterosato, which gives 758 species. Mr. Jeffreys proposed to deduct 31 of these species for probable varieties, and to add 39 species from the 'Porcupine' and 'Shearwater' expeditions, making altogether 766 Testaceous or shell-bearing species. The Nudibranchs and other naked or shell-less Mollusca described by Philippi (33 species), as well as the Cephalopoda described and figured by Verany (43 species), being added to the Testaceous species, there results a total number of 842 Mediterranean species. Of these no less than 622 species inhabit also the North Atlantic, so that only 222 species are at present supposed to be peculiar to the Mediterranean. Lists of the 39 and 222 species are subjoined; and the author fully expected that most if not all of those in the latter category would be hereafter found in the North Atlantic. According to the author's work on 'British Conchology,' there are 562 species in our own seas, exclusive of those dredged beyond the line of soundings in the 'Lightning' and 'Porcupine' expeditions. One of the most interesting results of the 'Porcupine' expeditions consisted in the discovery at considerable depths of living species of Mollusca which had been previously known as fossils only and were regarded as extinct. Many of these species occur in the newer Tertiary beds of Sicily, and a list of them is likewise subjoined. The author said in conclusion :—" We all profess to study the great book of Nature. But before we study we must be able to read; and who can say that he has read a single page, much less a whole chapter, of this mysterious volume? The sole knowledge we possess of the deep-sea Mollusca of the Mediterranean (those which inhabit depths exceeding 500 fathoms) is derived from a few casts of the dredge made in the 'Porcupine' expedition of 1870. The space thus partially explored was not much larger than this room, while the area of the Mediterranean contains many hundred thousands of square miles. Let us therefore compare the extent of our researches in this small nook or offset of the Atlantic with that of the work yet to be undertaken throughout the almost boundless area of the mighty ocean; and having made the comparison let us reflect, and then humbly confess our ignorance."

In replying to questions, Mr. Jeffreys said that the Suez Canal might hereafter lead to an interchange of the Mollusca; but he was not satisfied that more than one species (*Ringicula auriculata*) was common to the Mediterranean and the Red Sea.

Additions to the Marquis de Monterosato's Catalgue of Mediterranean Shells. From the 'Porcupine' and 'Shearwater' expeditions.

CONCHIFERA.

P. *Pleuronectia lævis*, Jeffr. MS. A single valve only. Off Rasel Amoush, coast of Tunis, 45 fathoms.
P. *Mytilus incurvatus*, Philippi (*Modiola*). Station 56a; 152 f. Fossil at Piagga in Sicily.
P. *Nucula tumidula*, Malm. St. 55; 1456 f. Atlantic also.
P. —— *convexa*, Jeffr. MS. 40-1456 f. Allied to *N. tenuis*, but more convex and square, with a straight cartilage-pit.
P. *Solenella cuneata*, Jeffr. MS. St. 51; 1415 f. Very distinct from *S. obtusa*, Sars.
P. *Leda lucida*, Lovén. St. 55; 1456 f. Atlantic.
P. —— *oblonga*, Jeffr. MS. St. 55; 1456 f.
P. —— *subrotunda*, Jeffr. MS. St. 55; 1456 f.
P. *Limopsis aurita*, Brocchi. Adventure Bank, 92 f. Atlantic also.

N.B. *Gouldia bipartita* of Monterosato's Catalogue has a conspicuous external ligament, and is a true *Astarte*.

Specimens of *Astarte triangularis*, of the same size and apparently of the same age, have the inside of the margin indifferently notched or quite smooth; some are notched, while others twice the size are smooth. All these specimens were dredged in the same spot.

S. *Cardita incurva*, Jeffr. MS. Fossil in Sicily (Monterosato)!
P. *Lyonsia formosa*, Jeffr. MS. St. 55; 1456 f. Atlantic also.
P. *Neæra obesa*, Lov. St. 55; 1456 f.: Adventure Bank, 92 f. Atlantic also, from Norway to the coast of Portugal.
P. *Pecchiolia insculpta*, Jeffr. MS. Off Jijeli, 40–80 f.
P. *Pholadomya Loveni*, Jeffr. MS. St. 55; 1456 f. A fragment only, but unmistakable. Atlantic also.

SOLENOCONCHIA.

P. *Dentalium incertum*, Ph., = *D. agile*, Sars. Adventure Bank, 92 f. Atlantic also.

GASTROPODA.

S. *Tectura fulva*, Müller. Atlantic also.
P. *Propilidium scabrum*, Jeffr. MS. Adventure Bank, 92 f. Resembling the young of *Gadinia Garnoti*, but having the internal septum of *Propilidium*.
P. *Trochus biangulatus*, Eichwald, = *T. ditropis*, S. Wood. Off Algesiras, 1-15 f.: St. 50; 51 f.
P. —— *suturalis*, Ph. St. 45; 207 f.: off Rasel Amoush, 45 f. Atlantic also.
P. —— *scabrosus*, Jeffr. MS. St. 55; 1456 f.
P. *Turbo Romettensis*, Seguenza, MS. St. 45; 207 f.
P. *Rissoa subsoluta*, Aradas. St. 50; 51 f.: St. 55; 1456 f. Adventure Bank, 92 f. Atlantic also.
P. —— *tenuisculpta*, Jeffr. MS. St. 53; 112 f.: Adventure Bank, 92 f. Atlantic also.
P. *Odostomia flexuosa*, Jeffr. MS. St. 50; 51 f.: St. 55; 1456 f. Adventure Bank, 92 f. Atlantic also.
P. —— *pulchra*, Jeffr. MS., = *O. canaliculata*, Ph.? Adventure Bank, 92 f.
P. —— (*Chemnitzia*) *acutecostata*, Jeffr. MS. St. 45; 207 f.: off Rasel Amoush, 45 f.
P. —— (*Chemnitzia*) *paucistriata*, Jeffr. MS. Benzert Road, 40–65 f. Atlantic also.
P. —— (*Eulimella*) *prælonga*, Jeffr. MS. St. 50; 51 f.: St. 55; 1450 f. Adventure Bank, 92 f. Atlantic also.
P. —— (*Eulimella*) *unifasciata*, Jeffr. MS., ? = *Eulima unifasciata*, Forbes. Adventure Bank, 92 f.
P. *Triforis aspera*, Jeffr. MS. Adventure Bank, 92 f. Atlantic also.

P. *Cerithiopsis horrida*, Jeffr. MS. Off Rasel Amoush, 45 f. Smyrna also (M'Andrew)!
P. —— *fibula*, Jeffr. MS. St. 45; 207 f.: Benzert Road, 40–65 f: off Rasel Amoush, 45 f.: Adventure Bank, 92 f. Canaries also (M'Andrew)!
P. *Defrancia tenera*, Jeffr. MS. Off Rasel Amoush, 45 f.
P. —— *gibbera*, Jeffr. MS. St. 50; 51 f.: Adventure Bank, 92 f.
P. *Pleurotoma nodulosa*, Jeffr. MS. St. 55; 1456 f.
P. *Utriculus striatulus*, Jeffr. MS. St. 45; 207 f.
P. *Actæon globulinus*, Forb. Adventure Bank, 92 f. Ægean (Forbes). Atlantic also.
P. *Bulla subrotunda*, Jeffr. MS. Off Jijeli, 40–80 f. Atlantic also.
P. *Philine flexuosa*, Sars. St. 45; 207 f. Norwegian also.

39 species.

Mediterranean Species which have not yet been noticed as Atlantic.

M. Monterosato's catalogue. P. 'Porcupine' expedition.
S. 'Shearwater' expedition.

BRACHIOPODA.

M. Argiope cordata, *Risso*, = N. Neapolitana, *Scacchi*.
M. Thecidium Mediterraneum, *Risso*.

CONCHIFERA.

M. Pecten hyalinus. *Poli*.
P. Pleuronectia lævis, *Jeffr. MS.*
M. Pinna nobilis, *Linn.*
M. Mytilus minimus, *Poli*.
P. —— incurvatus, *Ph.*
M. Lithodomus lithophagus, *L.*
M. Crenella arenaria, *Martin, MS.*
P. Nucula convexa, *Jeffr. MS.*
P. Leda oblonga, *Jeffr. MS.*
P. —— subrotunda, *Jeffr. MS.*
P. Solenella cuneata, *Jeffr. MS.*
M. Montacuta semirubra, *Monterosato*.
M. Scacchia ovata, *Ph.*
S. Cardita incurva, *Jeffr. MS.*
M. Cardium hians, *Brocchi*.
M. —— erinaceus, *L.*
M. —— oblongum, *Chemnitz*.
M. Crassatella planata, *Calcara*, = Gouldia modesta, *H. Adams*.
M. Venus cygnus, *Lamarck*.
M. —— effossa, *Birona*.
M. Tellina nitida, *Poli*.
M. Venerupis Lajonkairi, *Payraudeau*.
P. Pecchiolia insculpta, *Jeffr. MS.*
M. Clavagella Melitensis, *Broderip*.
M. —— angulata, *Ph.*
M. Teredo minima, *De Blainville*.

SOLENOCONCHIA.

M. Dentalium rubescens, *Deshayes*.
M. Cadulus ovulum, *Ph.*

GASTROPODA.

M. Chiton olivaceus, *Spengler*, = C. Siculus, *Gray*.
M. Chiton rubicundus, *O. G. Costa*, = C. pulchellus, *Ph.*
M. —— Rissoi, *Payr.*
M. —— Polii, *Ph.*
M. Patella ferruginea, *Gmelin*.
P. Propilidium scabrum, *Jeffr. MS.*
M. Emarginula Adriatica, *O. G. Costa*.
M. —— Huzardi, *Payr.*
M. —— solidula, *O. G. Costa*.
M. Fissurella costaria, *Basterot*.
M. Schismope striatula, *Ph.*
M. Cyclostrema exilissimum, *Ph.*
M. —— Jeffreysi, *Monter. MS.*
M. Trochus fanulum, *Gm.*
M. —— Guttadauri, *Ph.*
M. —— Adansoni, *Payr.*
M. —— Spratti, *Forbes*.
M. —— pygmæus, *Ph.*
M. —— divaricatus, *L.*
M. —— unidentatus, *Ph.*
P. —— biangulatus, *Eichw.*
P. —— scabrosus, *Jeffr. MS.*
M. Clanculus cruciatus, *L.*, = Monodonta Vieilloti, *Payr.*
M. —— glomus, *Ph.*
M. —— Jussieui, *Payr.*
M. Phasianella speciosa, *Mühlfeld*.
M. Turbo sanguineus, *L.*
P. —— Romettensis, *Seg. MS.*
M. Fossarus costatus, *Brc.*
M. Ervilia Mediterranea, *Monter.*
M. Rissoa auriscalpium, *L.*
M. —— cingulata, *Ph.*
M. —— Lanciæ, *Calc.*, = R. Philippiana, *Jeffr.*, = Alvania tessellata, *Schwart.*
M. —— Caribæa, *D'Orbigny*, = Alvania subareolata, *Monter.*
M. —— aspera, *Ph.*
M. —— scabra, *Ph.*
M. —— mutabilis, *Schw.*, = Canariensis, *D'Orb.*?
M. —— tenera, *Ph.*

M. Rissoa rudis, *Ph.*
M. —— Maderensis, *Jeffr. MS.*
M. —— fusca, *Ph.*
M. —— contorta, *Jeffr.*
M. Jeffreysia inflata, *Jeffr. MS.*
M. —— Alleryana, *Benoit, MS.*
M. —— cylindrica, *Jeffr.*
M. Cæcum Chiereghinianum, *Brusina.*
M. Vermetus arenarius, *L.*
M. —— triqueter, *Biv.*
M. —— glomeratus, *Biv.*
M. —— subcancellatus, *Biv.*
M. Siliquaria anguina, *L.*
M. Turritella subangulata, *Brc.*
M. Scalaria Cantrainei, *Weinkauff*, =S. muricata, *Tiberi.*
M. —— frondicula, *S. Wood.*
M. —— hispidula, *Monter. MS.*
M. —— pulcherrima, *Monter. MS.*
M. —— Monterosati, *De Stefanis, MS.*
M. Odostomia polita, *Biv.*, =Odontostoma Sicula, *Ph.*
M. ——vitrea, *Brus.*, =O. neglecta, *Tib.*, =O. elegans, *Monter.*
M. —— canaliculata, *Ph.*, =O. intermedia, *Brus.*
M. —— obliquata, *Ph.*
M. —— tricincta, *Jeffr.*
M. —— internodula, *S. Wood.*
M. ——striatula, *L.*, =O. varicosa, *Forb.*, =O. pallida, *Ph.*
M. —— unifasciata (Eulima), *Forb.*
P. —— acutecostata, *Jeffr. MS.*
M. Eulima microstoma, *Brus.*
M. —— Jeffreysiana, *Brus.*
M. Natica Dillwynii, *Payr.*
M. —— marmorata, *H. Adams.*
M. —— Guillemini, *Payr.*
M. —— Josephinia, *Risso*, =N. olla (*De Serres*), *Ph.*
M. Solarium pseudoperspectivum, *Brc.*, =S. discus, *Ph.*
M. Gyriscus Jeffreysianus, *Tib.*
M. Architea catenulata, *A. Costa*, =Cyclostoma delicatum, *Ph.* ?
M. Xenophora Mediterranea, *Tib.*
M. Sigaretus striatus, *De Serr.*, =S. haliotoideus, *Ph.*
M. Cancellaria coronata, *Sc.*
M. Cerithium conicum, *De Bl.*, =C. Sardoum *and* C. Peloritanum, *Cantraine.*
M. —— costatum, *Da Costa*, =C. ambiguum, *C. B. Adams*, =C. Lafondi, *Michaud.*
M. —— elegans, *De Bl.*, =C. lacteum, *Ph.*
P. Cerithiopsis horrida, *Jeffr. MS.*
M. Triton Seguenzæ, *Aradas & Benoit*, =T. variegatus, *Ph.*
M. Ranella reticulata, *De Bl.*, =R. lanceolata, *Ph.*
M. Typhis tetrapterus, *Bronn.*
M. Trophon pulchellus, *Ph.*
M. —— Syracusanus, *L.*
M. —— craticulatus, *L.*, =T. Brocchii, *Monter.*
M. Murex scalaroides, *De Bl.*, =M. distinctus (*De Cristofori & Jan*), *Ph.*
M. Lachesis granulata, *Tib.*
M. —— lineolata, *Tib.*
M. —— Folineæ (*Delle Chiaje*), *Ph.*, = L. areolata, *Tib.*
M. Pisania picta, *Sc.*, =Buccinum Scacchianum, *Ph.*
M. —— leucozona, *Ph.*
M. Cassidaria echinophora, *L.*
M. Doliopsis Crosseana, *Monter.*
M. Nassa gibbosula, *L.*
M. —— granum, *Lam.* (Buccinum grana).
M. Columbella columbellaria, *Sc.*, =C. Greci, *Ph.*
P. Defrancia tenera, *Jeffr. MS.*
P. —— gibbera, *Jeffr. MS.*
M. —— ? hystrix (*Jan*), *Bellardi.*
M. Pleurotoma clathrata, *De Serr.*, = P. rude *and* P. granum, *Ph.*
M. —— multilineolata, *Deshayes.*
M. —— pusilla, *Sc.*, =P. multilineolata, var. ?
M. —— tæniata, *Desh.*
M. —— Kieneri, *Maravigna*, =P. plicata, *Ph.*, =Raphitoma Philippii, *Weinkauff.*
P. —— nodulosa, *Jeffr. MS.*
M. Mitra zonata, *Marryat*, =M. Santangeli, *Maravigna.*
M. Mitra tricolor, *Gmelin*, =M. Savignyi, *Payr.*, =M. granum, *Forb.*
M. Cypræa physis, *Brc.*
M. Ovula carnea, *Gm.*
M. —— Adriatica, *G. B. Sowerby.*
M. Cylichna Jeffreysi, *Weink.*
P. Utriculus striatulus, *Jeffr. MS.*
M. Akera fragilis, *Jeffr.*
M. Scaphander turgidulus, *Forb.*, =Bulla diaphana, *Aradas*, =S. gibbulus, *Jeffr.*
M. Philine vestita, *Ph.*
M. Smaragdinella Algiræ (*Hanley*), *Weink.*
M. Doridium Meckelii, *Delle Ch.*
M. —— coriaceum, *Meckel*, =P. aplysiæforme, *D. Ch.*
M. Oxynoe olivacea, *Rafinesque*, =Bulla Gargottæ, *Calc.*, =Lophocercus Sieboldi, *Krohn*, =Icarus Gravesi, *Forb.*

M. Lobiger Serradifalci, *Calc.*, = L. Philippii, *Krohn.*
M. Aplysia longicornis, *Rang.*
M. —— virescens, *Risso*, = A. unguifera *and* A. petalifera, *Rang.*
M. Umbrella Mediterranea, *Lam.*
M. Tylodina Rafinesquii, *Ph.*
M. Gadinia Garnoti, *Payr.*
M. Melampus Firminii, *Payr.*

PTEROPODA.

M. Cymbulia Peroni, *Cuvier.*
M. Clio conica, *A. Costa.*

CEPHALOPODA.

M. Argonauta Argo, *L.*

162 species.

To these may be added the following Nudibranchs and other shell-less Mollusca which are not in Monterosato's Catalogue.

Ph. Philippi's work on the Mollusca of the Two Sicilies.

Ph. Eolis limacina, *Ph.*
Ph. —— Scacchiana, *Ph.*
Ph. —— peregrina, *Gm.*
Ph. —— minima, *Forskål.*
Ph. Tritonia quadrilatera, *Schultz.*
Ph. Tethys leporina, *L.*
Ph. Idalia crocea, *Ph.*
Ph. —— ramosa, *Cantr.*
Ph. —— cirrigera, *Ph.*
Ph. Doris Argo, *L.*
Ph. —— pseudo-argus, *Rapp.*
Ph. —— limbata, *Cuv.*
Ph. —— tomentosa, *Cuv.*
Ph. —— albescens, *Sch.*
Ph. —— elegantula, *Ph.*
Ph. Doris luteo-rosea, *Rapp.*
Ph. —— verrucosa, *L.*
Ph. —— elegans, *Cantr.*
Ph. —— Villafrancana, *Risso.*
Ph. —— cærulea, *Risso.*
Ph. —— Rappii, *Cantr.*
Ph. —— pustulosa, *Cantr.*
Ph. Gasteropteron Meckelii, *Kosse.*
Ph. Diphyllidia lineata, *Otto.*
Ph. —— pustulosa, *Sc.*
Ph. Notarchus punctatus, *Ph.*
Ph. Elysia fusca, *Ph.*
Ph. —— Neapolitana, *D. Ch.*

28 species.

And the following Cephalopods, which are also wanting in Monterosato's Catalogue.

V. Verany's Mollusques Méditerranéens. 1e Partie, Céphalopodes.

V. Eledone Aldrovandi, *De Ch.*
V. —— moschata, *Leach.*
V. Histioteuthis Bonelliana, *D'Orb.*
V. —— Ruppelli, *Ver.*
V. Loligo Alessandrinii, *Ver.*
V. —— æquipoda, *Rapp.*
V. —— Berthelotii, *Ver.*
V. —— Bianconi, *Ver.*
V. —— Coindetii, *Ver.*
V. —— Marmoræ, *Ver.*
V. —— Meneghinii, *Ver.*
V. —— Pillæ, *Ver.*
V. Loligopsis Veranyi, *Férussac.*
V. —— vermicularis, *Rapp.*
V. —— gigana, *Ver.*
V. Octopus Alderii, *Ver.*
V. —— catenulatus, *Fér.*
V. —— Carena, *Ver.*
V. —— Defillippii, *Ver.*
V. —— Koellikerii, *Ver.*
V. Octopus macropus, *Risso.*
V. —— Salutii, *Ver.*
V. —— tetracirrhus, *D. Ch.*
V. —— violaceus, *D. Ch.* (besides ten doubtful species of *Octopus*).
V. Onychoteuthis Lichtensteinii, *Fér.*
V. —— Krohnii, *Ver.*
V. —— margaritifera, *Rapp.*
V. —— Owenii, *Ver.*
V. —— Veranyi, *Rapp.*
V. —— sicula, *Kr.*
V. Rossia dispar, *Rapp.*
V. Sepioteuthis sicula, *Rapp.*

32 species.

Testaceous	162
Nudibranchs	28
Cephalopods	32
Total........	222 species.

Fossil in Sicily and lately found by me living in the North Atlantic.

P. 'Porcupine' expeditions.

P. Terebratula sphenoidea, *Ph.*
P. —— septata, *Ph.*
P. Rhynchonella Sicula, *Seg. MS.*
P. Leda acuminata, *Jeffr.*, =L. Messanensis, *Seg. MS.*
P. —— pusio, *Ph.*
P. Limopsis minuta, *Ph.* (Pectunculus).
P. Pecchiolia acutecostata, *Ph.* (Hippagus).
P. —— granulata, *Seg.* (Verticordia).
P. Dentalium incertum, *Ph.*
P. Siphonodentalium, *sp. ined.*
P. Fissurisepta papillosa, *Seg.*
P. —— rostrata, *Seg.*
P. Trochus minimus, *Seg. MS.* (Margarita).
P. —— Ottoi, *Ph.*
P. —— suturalis, *Ph.*
P. Trochus gemmulatus, *Ph.*
P. —— reticulatus, *Ph.* (Solarium).
P. Gen. ined. (fam. Trochidæ) monocingulatus, *Seg.* (Trochus).
P. Turbo glabratus, *Ph.* (Trochus), and var., =Trochus filosus, *Ph.*
P. Trachysma delicatum, *Ph.* (Cyclostoma), =Architea catenulata, *A. Costa?*
P. Rissoa subsoluta, *Ar.*
P. Odostomia plicatula, *Brc.* (Turbo).
P. Solarium moniliferum, *Bronn.*
P. Mitra Marini, *Libassi.*
P. —— obesa, *Foresti* (not of Reeve).
P. Pedicularia Deshayesiana, *Seg.*

26 species.

On a Peach-coloured Bacterium. By E. Ray Lankester, *M.A.*

Embryological Observations bearing on the Genealogy of the Mollusca. By E. Ray Lankester, *M.A.*

On Birds observed in the West Riding of Yorkshire in former and recent years. By T. Lister, *Barnsley.*

The numbers observed are given, and a few of the rarest are placed in connexion with each family.

Order I. Raptores.

Family.	Species.	Rarest.
Falconidæ.	15	Osprey, Peregrine Falcon, Kite, Red-footed Falcon, Hen Harrier, Montagu's Harrier, Goshawk, Common Buzzard, Rough-legged Buzzard, Honey Buzzard, Marsh Harrier, Swallow-tailed Kite.
Strigidæ.	8	Eagle Owl, Snowy Owl, Scops Eared Owl, American Mottled Owl.

Order II. Insessores.

Laniidæ.	3	Red-backed Shrike, Woodchat.
Muscicapidæ.	2	Pied Flycatcher (local).
Cinclidæ.	1	
Turdidæ.	6	
Sylviidæ.	20	Black Redstart, Firecrest, Reed Warbler, Nightingale (the last sweet warbler in South Yorkshire yearly; instances as far north as York and Ripon).
Troglodytidæ.	1	
Certhiidæ.	1	
Sittidæ.	1	
Paridæ.	7	Crested Tit, Bearded Tit.
Ampelidæ.	1	Bohemian Waxwing (1873, and former instances).
Motacillidæ.	3	

Family.	Species.	Rarest.
Anthidæ.	2	
Alaudidæ.	2	
Emberizidæ.	5	Snow-Bunting (in severe winters), Cirl Bunting (rare).
Fringillidæ.	12	Siskin, Twite (in winter, from the Moorland Hills).
Loxiidæ.	1	Crossbill (many instances).
Sturnidæ.	2	Rose-coloured Pastor (several instances).
Corvidæ.	8	Raven (nearly extinct), Chough.
Picidæ.	5	Black Woodpecker, Barred Woodpecker.
Upupidæ.	1	Hoopoe (near Barnsley, 1847; instances from other parts of the Riding).
Cuculidæ.	1	
Alcedinidæ.	1	
Meropidæ.	1	Bee-eater (1849).
Coraciidæ.	1	Roller (several instances).
Hirundinidæ.	3	
Cypselidæ.	1	
Caprimulgidæ.	1	
		Order III. Rasores.
Columbidæ.	4	Turtledove (rare), Stockdove (local).
Phasianidæ.	1	
Tetraonidæ.	5	Black Grouse (a few naturalized), Red-legged Partridge.
		Order IV. Grallatores.
Otididæ.	1	Little Bustard (rare instance).
Charadriidæ.	9	Cream-coloured Courser (2 or 3 instances), Dotterel, Oyster-catcher, Turnstone.
Scolopacidæ.	20	Greenshank, Redshank, Little Stint, Grey Phalarope, Black and Bar-tailed Godwit, Curlew, Whimbrel, Curlew Sandpiper, Knot, Purple Sandpiper, Avocet, Wood Sandpiper, Reeve (female of Ruff, near Barnsley, 1872). The last four very rare instances, the rest occurring occasionally.
Plataleidæ.	1	Spoonbill (supposed escape).
Ciconiidæ.	1	White Stork (3 or 4 instances).
Ardeidæ.	6	Squacco Heron, Little Egret, Great and Little Bittern, Purple Heron (the last three in recent years).
Rallidæ.	5	Spotted Crake, Little Crake (rare instance, recently).
		Order V. Natatores.
Anatidæ.	28	Hooper (flocks, winter 1871–72), Garganey, Harlequin Duck, Gadwall, Long-tailed Duck, Pink-footed Goose, Velvet and Common Scoter (both as recently as winter of 1872–73).
Colymbidæ.	3	All 3 Divers in recent years.
Podicipidæ.	5	All the Grebes in recent years.
Alcidæ.	2	Puffin, Little Auk (caught near Barnsley, 1854, in my possession; many instances in West Riding).
Pelecanidæ.	2	Gannet, Cormorant.
Laridæ.	14	Sandwich Tern, Roseate Tern, Glaucous Gull, Greater Shearwater, Richardson's Skua, Pomerine Skua.
Procellaridæ.	3	Fork-tailed Petrel, Bulwer's Petrel, Stormy Petrel (one brought to me picked up in Barnsley, 1846; instances in other parts of the West Riding).

This brief summary of birds observed in West and South Yorkshire is drawn up from personal observation of myself and members of the West-Riding Naturalist Societies, and the 'Monthly Recorder,' the organ of their communications. Many species are recorded on the authority of our late neighbour, Charles Waterton of Walton Hall, whose protection of all birds gave him superior opportunities of

studying them; their tameness in the absence of firearms brought them readily within the range of the eye or telescope. A list prepared in 1844 by Dr. Farrar, late of Bradford, formerly of Barnsley, was placed in my hands, also an account of Yorkshire birds, drawn up in the same year by Thomas Allis, of York, including notices from Hugh Reid, Bird-stuffer, Doncaster; Henry Denny, late Curator of the Philosophical Hall, Leeds; William Eddison, Huddersfield; John Heppenstall (father and son), of Sheffield; A. H. Strickland; R. Leyland, Halifax; S. Gibson, Hebden Bridge; and the Rev. F. O. Morris, who has observed in all the three Ridings of York. The Rev. F. O. Morris and T. Allis are the only survivors of these painstaking naturalists. From the above sources of information we may get an idea of the birds noticed in the West Riding within the recollection of living observers and in present times.

We may form an estimate of them thus. Taking the 'Zoologist's' List, compiled from Yarrell, of resident birds, migrants, and occasional visitants—out of 29 raptorial birds on that list, we have had 23 recorded; of 135 insessorial birds, 91; of 13 rasorial birds, 10 have been recorded: thus of 177 generally designated Land Birds, we have had 124; of 64 grallatorial birds, 43; of 90 natatorial birds, 57 have been recorded: thus of 154 wading or swimming birds we have a total of 100.

Another mode of showing the comparative numbers strikes us. Take the List in Mr. Harting's excellent 'Ornithological Handbook of Residents and Migrants,' separated by him from the List of rare and accidental visitors to Great Britain. The species there enumerated are:—of raptorial birds 20, of insessorial 105, of rasorial 12, of grallatorial 64, of natatorial 90—making totals of land birds 137, of water birds 124, totals of both divisions 261. Here is shown a greater proportion for the West Riding, 224 (including a few on the List of rare or accidental visitors) having been recorded out of the 261 considered as British birds. This is a large number considering the wanton extermination to which many of the feathered tribes are doomed. It shows the capabilities this Riding possesses to gratify the field ornithologist, which would be greatly increased if half the care were taken in preserving our persecuted birds, after the manner of Waterton and other landowners following to some extent in his steps, as there is excess of zeal manifested to capture or destroy every rare bird that visits or resides within the limits of this extensive Riding. Our county presents great variety in physical formation, from the Pennine range of Mountain-limestone and Millstone-grit west, over the Coal-formation with undulating slopes, valleys, streams, canals, pools, fine woodlands, and noble parks, over the Magnesian limestone to the Lias, Oolite, and Chalk cliffs of the East and North Riding, which (though not within the limits to which this paper is confined) afford suitable breeding-haunts and places of resort to many birds which frequently favour the inland parts of Yorkshire with their presence.

On a new Insect belonging to the Family Ephemeridæ, *with Notes on the Natural History of that Family. By* R. MacLachlan, *F.L.S.*

The author gave an account of a new species of the family recently received from Canterbury, New Zealand, remarkable for its abdomen, which was very robust, and the seventh to the ninth segments had broad, horny, acute, wing-like expansions on each side, so that this part of the body resembled that of some Myriopod or Crustacean. He proposed for it the name *Onisciyaster Wakefieldi*, after its captor, Mr. C. M. Wakefield. Although the earlier stages were unknown, he considered it probable that the abdominal formation was reproduced in the imago; and hence the latter might be looked upon as a degraded form. A somewhat analogous abdominal structure was to be seen in the immature condition of the American *Bætisca obesa*, as demonstrated by Walsh, though this latter possessed an enormous thoracic development, forming a carapace under which the rudimentary wings were concealed. And in connexion with this, the author alluded to the so-called crustaceous genus *Prosopistoma* of Latreille, which the French entomologists MM. Joly, father and son, had recently asserted, with much appearance of truth, is the immature condition of an insect of this group, they having found decided indications of tracheal respiration in it.

Anatomy and Physiology.

Address to the Department of Anatomy and Physiology. *By* Professor Rutherford, *F.R.S.E.*

In addressing you upon the subjects of anatomy and physiology, I would invite your attention to some of the features which characterize these departments of biology at this present time, and to some recent advances in physiology, the consideration of which you will find to be possessed of deep interest and importance.

State of Anatomy.

Anatomy, dealing as it does merely with the structure of living things, is a far simpler subject than physiology, whose province it is to ascertain and explain their actions. It was not a difficult thing to handle such instruments as a knife and forceps, and with their aid to ascertain the coarser structure of the body. Accordingly, the naked-eye anatomy of man has been fully investigated; and although the same cannot be said of that of many of the lower animals, it is nevertheless, as far as this kind of inquiry is concerned, a mere question of time as regards its completion. But minute or microscopic anatomy is in a different position. Requiring, as it does, the microscope for its pursuit, it could not make satisfactory progress until this instrument had been brought to some degree of perfection. Doubtless much advantage is still to be derived from improvements in the construction of this instrument; but probably most of the future advances in our knowledge of the structure of the tissues and organs of the body may be expected to result from the application of new methods of preparing the tissues for examination with such microscopes as we now have at our disposal. This expectation naturally arises from what has been accomplished in this direction during the last fifteen years. For example, what valuable information has been gained regarding the structure of such soft tissues as the brain and spinal cord by hardening them with such an agent as chromic acid, in order that these tissues may be cut into thin slices for microscopical study. How greatly has the employment of such pigments as carmine, aniline, and logwood facilitated the microscopical recognition of certain elements of the tissues. What a deal we have learned regarding the structure of the capillaries and the origin of lymphatics by the effect which nitrate of silver has of rendering distinctly visible the outlines of epithelial cells. What signal service chloride of gold has rendered in tracing the distribution of nerves by the property which it possesses of staining nerve-fibrils, and thereby greatly facilitating their recognition amidst the textures. Moreover of what value osmic acid has been in enabling us to study the structure of the retina. In the hands of Lockhart Clarke, Recklinghausen, Cohnheim, Schultze, and others, these agents have furnished us with information of infinite value; and those who would advance microscopical anatomy may do so most rapidly by working in the directions indicated by these investigators. In human microscopical anatomy, indeed, there only remain for investigation things which are profoundly difficult—such as, for example, the structure of the brain, the peripheral terminations of nerves, the development of nerve-tissue, and other subjects equally recondite. But in the field of comparative anatomy there is far greater scope for the histological investigator. He has only to avail himself of those reagents and methods which have recently proved so useful in the microscopical anatomy of the vertebrates; he has only to apply those more fully than has yet been done to the invertebrates, and he will scarcely fail to make discoveries. For the lover of microscopical research there is, moreover, a wide field of inquiry in the study of comparative embryology—that is to say, in the study of the development of the lower animals. Since it has become clear that a knowledge of the precise relations of living things one to another can only be arrived at by watching the changes through which they pass in the course of their development, research has been vigorously turned in this direction; and although an immense mass of facts has long since been accumulated regarding this question, Parker's brilliant researches on the development of the skull give an indication of the great things which we may yet anticipate from this kind of research. Speaking of micro-

scopical study before this audience, I cannot but remember that in this country more than in any other we have a number of learned gentlemen who, as amateurs, eagerly pursue investigations in this department. I confess that I am always sorry to witness the enthusiastic perseverance with which they apply themselves to the prolonged study of markings upon diatoms, important though these be in many respects, seeing that they might direct their efforts to subjects which would repay them for their labours far more gratefully. I would venture to suggest to such workers that it is now more than ever necessary to abandon all aims at haphazard discoveries, and to approach microscopy by the only legitimate method, of undergoing a thorough preliminary training in the various methods of microscopical investigation by competent teachers, of whom there are now plenty throughout the country.

State of Physiology.

With regard to physiology, the present standpoint is not so high as in the case of anatomy. Physiology, resting as it does upon a tripod consisting of anatomy, physics or mechanics, and chemistry, is many-sided. The most minute anatomy, the most recondite physics, and the most complex chemistry have all to be taken into account in the study of the physiology of living things; so that it is not surprising that it should, in its development, lag behind the comparatively elementary subject anatomy. Until not so very long ago anatomy and physiology were, in most of our medical schools, taught by the same professor, who, although professing to teach both subjects, was generally more of an anatomist than a physiologist. This arrangement gave to physiology a bias which was eminently anatomical; and this bias continued in many quarters, notwithstanding the separation of the physiological from the anatomical tuition. I am aware that there are still some distinguished anatomists who intermingle physiological with anatomical teaching. I am not questioning the usefulness of the practice when carried to a moderate extent. I wish merely to point out what appears to me to have been a result of the practice, and I believe that the result was to give to physiology an anatomical tendency. It was natural for the anatomist who dealt with visible structure to constantly refer to this in explaining physiological action or function. The physiologist with the anatomical tendency always tried to explain a difference in the action or function of a part by a difference in its evident structure; and when his microscope failed to show any structural difference between the cells which form saliva and those which produce pancreatic fluid, between the egg of a rabbit and that of a dog, he, baffled on the side of anatomy, was too ready to adopt the conclusion that, inasmuch as *the microscope reveals no difference* in the structure, there is really no structural difference between them, and that the only way in which the difference in action can be explained is by having recourse to the old hypothesis, that the metamorphoses of matter and the actions of force are in the living world regulated by a metaphysical entity termed a vital principle, and that dissimilar actions by similarly constructed parts are only to be explained by referring them to the operations of this principle. [After alluding further to the hypothesis of the vital principle and its supposed actions, and after stating that he did not follow the teaching of those who still adhere to this doctrine, the author said that, viewed from the physical side, there appears to be no reason for supposing that two particles of protoplasm, which possess a similar microscopic structure, must act in the same way; for the physicist knows that molecular structure and action are beyond the ken of the microscopist, and that within apparently homogeneous jelly-like particles of protoplasm there may be differences of molecular composition and arrangement which determine widely different properties.]

A great change is now taking place in physiological tuition in this country—a superabundance of physiological anatomy and an almost entire absence of experiment are no longer its characteristic features. The study of physics, too much neglected, is happily now being more and more regarded as important in the preliminary training of the physiologist as the study of anatomy and of chemistry; and I trust that the day is not far distant when in our medical schools the thorough education of our students in mathematics and physics will be insisted upon as absolutely essential elements in their preliminary education. Until this is done phy-

siology will not advance in this country so rapidly as we could wish. I would not in this place have alluded to a question concerning medical education, but for the fact that the progress of physiology will always greatly depend upon the education of medical men; for only those who are conversant with physics and chemistry, and who, in addition, are acquainted with the phenomena of disease (that is to say with abnormal physiological conditions) can handle physiology in all its branches. Physiology owes not a little to a study of pathology—that is, of abnormal physiological states. The study of a diseased condition has on several occasions given a clue to the discovery of the function of an organ. Nothing was known regarding the function of the spleen until the pathologist observed that an increase in the number of white corpuscles in the blood is commonly associated with an enlargement of this organ. Hence arose the now accepted doctrine that the spleen is concerned in the formation of blood-corpuscles. The key to our knowledge of the functions of certain parts of the brain has also been supplied by a study of the diseased conditions of that organ. The very singular fact that the right side of the body is governed by the left, and not by the right, side of the brain, was ascertained by observing that palsy of the right side of the body is associated with certain diseased conditions of the left side of the brain; that the corpus striatum is concerned in motion, while the optic thalamus is concerned in sensation, and that intellectual operations are manifested specially through the cerebral hemispheres, are conclusions which were indicated by the study of diseased conditions. Moreover, by the pursuit of the same line of inquiry, the key has been given to the discovery of many other facts regarding the brain functions. Some years ago M. Broca made the remarkable observation that, when a certain portion in the front part of the left side of the brain becomes disorganized by disease, the person loses the power of expressing his thoughts by words, either spoken or written. He can comprehend what is said to him, his organs of articulate speech are not paralyzed, and he retains his power of writing, for he can copy words when told to do so; but when he is asked to give expression to his thoughts by speaking or by writing, or even to tell his name, he is helpless. With a palsy of a portion of his brain, he has lost his power of finding words; but although he has lost this power, his intelligent perception of what passes around him and what is said to him is not lost. It is true that this condition of aphasia, as it is termed, has been found to exist when various parts of the brain have been diseased; for example, it has been found to coexist with a diseased state of the posterior instead of the anterior part of the cerebrum. This fact renders it very difficult as yet to assign a precise locality to the faculty of speech. It is not, however, my intention to discuss this question, for my object is merely to show how the study of disease has given a clue to the physiologist. Broca's observation led to the thought that, after all, the dreams of the phrenologists would be realized, *in so far* as they supposed that the various mental operations are made manifest through certain definite territories of the brain.

It has until lately been supposed that the convolutions of the cerebrum are entirely concerned in purely intellectual operations; but this idea is now rendered doubtful. It is probable, from recent researches, that in the cerebral convolutions (that is, in the part of the brain which was believed to minister merely to intellectual manifestations) there are nerve-centres for the production of voluntary muscular movements in various parts of the body. It has always been taught that the convolutions of the brain, unlike nerves in general, cannot be stimulated by means of electricity. This, although true as regards the brains of pigeons, fowls, and perhaps other birds, has been shown by Fritsch and Hitzig to be untrue as regards mammals. These observers removed the upper portion of the skull in the dog, and stimulated small portions of the exposed surface of the cerebrum by means of weak galvanic currents; and they found that when they stimulated certain definite portions of the surface of the convolutions in the anterior part of the cerebrum, movements are produced in certain definite groups of muscles on the opposite side of the body. By this new method of exploring the functions of the convolutions of the brain, these investigators showed that, in certain cerebral convolutions, there are centres for the nerves presiding over the muscles of the neck, the extensor and adductor muscles of the forearm, for the flexor and rotator muscles of the arm, the muscles of the foot, and those of the face. They,

moreover, removed the portion of the convolution on the left side of the cerebrum, which they had ascertained to be the centre for certain movements of the right fore limb, and they found that after the injury thus inflicted, the animal had only an imperfect control over the movements of the part of the limb in question. Recently, Dr. Hughlings Jackson, from the observation of various diseased conditions in which peculiar movements occur in distinct groups of muscles, has adduced evidence in support of the conclusion that in the cerebral convolutions are localized the centres for the production of various muscular movements. Within the last few months these observations have been greatly extended by the elaborate experiments of my late pupil and assistant, and now able colleague in King's College, Prof. Ferrier.

Adopting the method of Fritsch and Hitzig (but instead of using galvanic he has employed Faradaic electricity, with which, strange to say, the investigators just mentioned obtained no very definite results), he has explored the brain in the fish, frog, dog, cat, rabbit, and guineapig, and lately in the monkey. The results of this investigation are of great importance. He has explored the convolutions of the cerebrum far more fully than the German experimenters, and has investigated the cerebellum, corpora quadrigemina, and several other portions of the brain not touched upon by them. There is perhaps no part of the brain whose function has been more obscure than the cerebellum. Dr. Ferrier has discovered that this ganglion is a great centre for the movements of the muscles of the eyeballs. He has also very carefully mapped out in the dog, cat, &c. the various centres in the convolutions of the cerebrum which are concerned in the production of movements in the muscles of the eyelids, face, mouth, tongue, ear, neck, fore and hind feet, and tail. He confirms the doctrine that the corpus striatum is concerned in motion, while the optic thalamus is probably concerned in sensation, as are also the hippocampus major and its neighbouring convolutions. He has also found that in the case of the higher brain of the monkey there is what is not found in the dog or cat—to wit, a portion in the front part of the brain, whose stimulation produces no muscular movement. What may be the function of this part, whether or not it specially ministers to intellectual operations, remains to be seen. These researches mark the commencement of a new era in our knowledge of brain function. Of all the studies in comparative physiology there will be none more interesting, and few so important, as those in which the various centres will be mapped out in the brains throughout the vertebrate series. A new, but this time a true, system of phrenology will probably be founded upon them: by this, however, I do not mean that it will be possible to tell a man's faculties by the configuration of his skull; but merely this, that the various mental faculties will be assigned to definite territories of the brain, as Gall and Spurzheim long ago maintained, although their geography of the brain was erroneous.

I have alluded to this subject, not only because it affords an illustration of the service which a study of diseased conditions has rendered to physiology, but also because these investigations constitute the most important work which has been accomplished in physiology for a very considerable time past.

Revival of Physiology in England.

We may, I think, term this the renaissance period of English physiology. It seems strange that the country of Harvey, John Hunter, Charles Bell, Marshall Hall, and John Reid should not always have been in the front rank as regards physiology. The neglect of physics must be admitted as a cause of this; it is also to be attributed to the, until a few years ago, almost entire absence of experimental teaching; but it would be unjust not to attribute it, in great measure, to the limited appliances possessed by our physiologists. It is to be remembered that physiology could not be successfully cultivated without proper laboratories, with a supply of expensive apparatus. Without endowments from public or private resources, how can such institutions be properly fitted up and maintained by men who can, for the most part, only turn to physiological research in moments snatched from the busy toil of a profession so laborious as that of medicine? In defiance of these difficulties we are now striving to hold our place in the physiological world. A new

system of physiological tuition is rapidly extending over the country. In the London schools, in Edinburgh, Cambridge, Manchester, and elsewhere, earnest efforts are being made to give a thoroughly practical aspect to the tuition of our science; and, notwithstanding the imperfect results which must necessarily ensue in the absence of suitable endowment, we can nevertheless point to the fact that the effect of these efforts has been to awaken a love for physiological research in the mind of many a student; and the results of this awakening are already apparent in the archives of the Royal Societies, in the 'Journal of Anatomy and Physiology,' and elsewhere. But physiological research is most expensive and laborious, and it is, moreover, unremunerative. The labours of the physiologist are entirely philanthropic; all his researches do nothing but contribute to the increase of human happiness by the prevention of disease and the amelioration of suffering; and I would venture to suggest to those who are possessed of wealth and of a desire to apply it for the benefit of society, that, in view of the wholly unselfish and philanthropic character of physiological labours, they could not do better than endow laboratories for the prosecution of physiological research.

We anticipate great benefit to the community not only from an advance of physiology, but from a diffusion of a knowledge of its leading facts amongst the people. This is now being carried out in our schools on a scale which is annually increasing. Thanks to the efforts of Huxley, the principles of physiology are now presented in a singularly palatable form to the minds of the young. The instruction communicated does not consist of technical terms and numbers, but in the elucidation of the principal events which happen within our bodies, together with an explanation of the treatment which they must receive in order to be maintained in health. Considering how much may be accomplished by these bodies of ours if they be properly attended to and rightly used, it seems to be a most desirable thing that the possessor of the body should know something about its mechanism, not only because such knowledge affords him much material for suggestive thought—not only because it is excellent mental training to endeavour to understand the why and the wherefore of the bodily actions—but also because he may greatly profit from a knowledge of the conditions of health. A thorough adoption of hygienic measures (in other words, of measures which are necessary to preserve individuals in the highest state of health) cannot be hoped for until a knowledge of fundamental physiological principles finds its way into every family. This country has taken the lead in the attempt to diffuse a sound knowledge of physiological facts and principles among the people, and we may fairly anticipate that this will contribute not a little to enable her to maintain her high rank amongst nations; for every step which is calculated to improve the physiological state of the individual must inevitably contribute to make the nation successful in the general struggle for existence.

On the Movements of the Glands of Drosera*.

By Alfred W. Bennett, *F.L.S.*

The glands which fringe the margin of the leaf and cover the upperside of the leaf of *Drosera* have been shown by previous observers not to be hairs in the true sense of the term, *i. e.* mere cellular expansions of the epidermis, but to be integral parts of the leaf, with a fibro-vascular bundle containing spiral threads (in other words, a vein or nerve of the leaf) running through them, and even to be furnished with stomata. The glands excrete at all times, when in a healthy condition, a white viscous gluten, which quickly entraps any small insect that settles upon the leaf, gradually holding it down more and more as it struggles, till escape is hopeless. The glands soon begin to move towards the imprisoned insect; but this movement is not very conspicuous at first, and is very much more decided after the insect has almost completely ceased to struggle, thus appearing not to be due to any "contractile tissue" in the leaf which is irritated by the movements of the insect. After the lapse of some time the whole of the glands of the leaf, even those which are at a considerable

* Quart. Journ. Micr. Soc., Oct. 1873.

distance from the insect, are found to be bending over towards it, and to be almost in contact with it. After a time the insect is to all appearance digested, actually supplying the tissue of the leaf with nourishment. Very nearly the same effect was produced by substituting for the fly a piece of raw meat, the movements of the glands being somewhat slower, but ultimately almost as complete, the meat being apparently digested in the same manner. On other leaves were placed a minute piece of wood and a small piece of worsted; and in neither of these cases was the least change perceptible, after a considerable time, in the position of the glands nor of the object itself.

On the Action of Alcohol on Warm-blooded Animals. By Dr. BINZ, *of Bonn.*

Physiological Researches on the Nature of Cholera. By Dr. LAUDER BRUNTON.

The search after a true remedy for cholera, the author thought, had hitherto been fruitless. The cause of the disease was now generally admitted to be a poison of some sort which could be transmitted from one person to another; but there must also be a proper soil for the development of the poison—in other words, the blood and tissues must be in such a state that it can act upon them.

In the state of collapse there was constant vomiting and purging, and the intestinal canal was speedily washed clean out, the stools consisting of the secretion alone; the blood stagnated in the great veins of the thorax and abdomen, and left the skin shrunken, pale, and cold, the interior of the body being hotter even than in a state of high fever. That blood which filled the small cutaneous veins being no longer driven forward by fresh supplies from the arteries, became completely deoxidized and black, imparting to the surface a livid hue. It still retained its power to take up oxygen and give off carbonic acid; but, notwithstanding this, it passed so slowly through the pulmonary vessels that only about one third of the usual quantity of carbonic acid was given off from the lungs; and little oxygen being taken in, there was a distressing feeling of want of breath. At the same time the voice was hoarse, low, and weak; but this seemed to be simply a consequence of the general exhaustion of the patient.

The symptoms of cholera all arose from disturbance of the circulation and alteration of the intestinal secretion; and it might be thought that the only means of removing those conditions would be to eliminate from the body that poison which was producing these effects, and that so long as it was still circulating in the blood, any remedy which was simply intended to counteract it would be administered in vain. But the researches of Fraser and others on antagonism had shown that the elimination of a poison was not required in order to prevent its injurious or fatal action; the administration of an antidote would deprive it of its hurtful power; and as it was with other poisons so might it be with that of cholera. It occurred to Dr. Brunton that if any poison should possess actions similar to those of cholera-poison, an antidote to it might possibly prove to be a remedy for cholera. He therefore began to look for a drug which would produce the same changes in the circulation which occurred in cholera. These were, he believed, first attributed by Dr. Parkes to spasmodic contraction of the pulmonary vessels, which prevented the blood from passing through them; and this opinion had found a warm supporter in Dr. George Johnson. Most of the symptoms, though not all, could be explained on this hypothesis.

Professor Schmiedeberg, in investigating the physiological action of a poisonous mushroom the (*Amanita muscaria* or *Agaricus muscarius*), noticed that when given to animals it caused great dyspnœa, and at the same time the arteries became empty, so that when cut across hardly a drop of blood issued from them—the very condition which existed in cholera. Administering atropia to the warm-blooded animals suffering from these symptoms, Professor Schmiedeberg found that they at once recovered. He had not thought at all, however, of contraction of the pulmonary vessels as a cause of dyspnœa. He attributed it rather to excitement of the nervous centre in the medulla oblongata, which regulates the respiratory move-

ments; but as the effect of atropia itself is to excite the nervous centre, it ought, according to his supposition, to have increased instead of removing the breathlessness. When the idea that the dyspnœa was due to contraction of the pulmonary capillaries suggested itself to Dr. Brunton, he proceeded to test it by experiment. He first gave a rabbit such a dose of chloral hydrate as to deprive it of all sensibility, then put a tube into the windpipe and connected it with a pair of bellows. He was thus able to inflate the animal's lungs at regular intervals and keep up respiration artificially when the animal could no longer breathe itself. He next opened the thoracic cavity so as to observe the slightest change in the lungs or heart. He injected a little muscarin into the jugular vein, when the lungs which had been previously rosy became blanched, the right side of the heart swelled up, the veins passing to it became enormously distended, and the left side of the heart almost empty. Shortly afterwards he injected a little atropia into the jugular vein. At once the effects of the muscarin disappeared, and every thing assumed its normal appearance. From the want of muscarin he had not pursued his investigations, but hoped shortly to do so.

Hitherto he had proceeded on the assumption that Drs. Parkes's and Johnson's theory of cholera was correct, and that the stoppage of the circulation in cholera was due to contractions of the arterioles of the lungs, as it was in muscarin-poisoning. In poisoning by muscarin the great veins of the thorax and abdomen and the right side of the heart seemed to be almost equally distended, and exactly the same condition was found in persons who had died of cholera. But it was not certain that the right side of the heart was always so much distended during life, even when the symptoms of cholera were present in their most pronounced form. It would almost seem that the veins dilated still more in cholera-collapse than they did in muscarin-poisoning. Nitrite of amyl has the power of dilating the arterioles throughout the body, and in those of the lungs also; but it was found practically to be of no use in cholera. The pulse might become a little stronger and the surface a little warmer, but the improvement was so slight that it is hardly worth mentioning, and the patient felt no better for the medicine either when inhaled or when injected subcutaneously. If the weakness of the pulse depended only on contraction of the vessels in the lungs, this result would be astonishing; but if they supposed it to be caused by dilatation of the great veins, it was just what they would expect. From these and other facts, Dr. Brunton concluded that the veins were dilated, and that therefore some remedy must be employed which would make them contract. There were very few experiments on the contractility of the veins; but in the condition of depression or shock following severe injuries, in which the veins were much dilated, digitalis had been found useful, and it might prove useful in cholera also. Atropia had been lately tried in cholera by an American practitioner with considerable success, and it seemed deserving of a more extensive trial.

It would not do, however, to consider the action of any proposed remedy for cholera on the circulation alone, and to leave out of account its effect upon the intestinal secretion. He therefore set to work to discover the action of atropia upon the intestinal secretion. Since the effect of cholera upon the intestine was the same as that of division of its nerves, which was one cause of secretion, they were justified in believing that if any drug could stop the secretion in Moreau's experiment of dividing the intestinal nerves it was likely to have a similar effect on cholera. Now atropia had remarkable power to stop secretion from the salivating and sweat glands when their nerves are irritated, rendering the mouth and skin quite dry. What its effect on paralytic secretion in the salivating glands might be he did not know; but thinking that it might arrest the flow of fluid into the intestine, he repeated Moreau's experiment and injected some solution of atropia into the vein of the animal. On killing it some hours afterwards, he found that there was fluid in that part of the intestine the nerves of which had been divided. The dose, however, was not large; and he comforted himself with the hope that a large dose might do, though a small one would not. He afterwards tested the power of atropia to check the secretion induced by injection of sulphate of magnesia into the intestine, both by injecting a mixture of sulphate of magnesia and atropia into the intestine and by injecting sulphate of magnesia alone into the bowel, and a solution of atropia into the veins. In both cases he used very large doses of atropia, but

they had not the slightest effect upon the secretion. The result was disappointing, and rendered the use of atropia in cholera somewhat doubtful. It was, however, difficult to foretell the effect of any drug under particular circumstances, and he should therefore continue his experiments.

The points to which he wished to direct particular attention were these:—

(1) That, assuming Parkes's and Johnson's theory to be correct, and the impeded circulation in cholera to be due to obstruction in the pulmonary vessels, atropia was likely to prove beneficial to a certain extent; and since it had been empirically found to be useful in the disease, it ought to receive a fair trial at the hands of the medical profession.

(2) The fact that the right side of the heart was not dilated during life in cholera patients, as well as the uselessness of nitrite of amyl, which dilated the pulmonary vessels, showed that Parkes's and Johnson's theory was imperfect, and that one of the most important pathological conditions in cholera-collapse consisted in an active dilatation of the thoracic and abdominal veins. Any remedy, to be useful in cholera, must have the power of counteracting this condition; and the administration of digitalis in cholera-collapse might be useful.

(3) The profuse secretion from the bowels in cholera was due to paralysis of some of the intestinal nerves; and a remedy which will arrest it was still a desideratum.

On some Abnormal Effects of Binocular Vision. By A. S. Davis.

On the Action of Light on the Retina and other Tissues. By Dr. Dewar *and* Dr. MacKendrick.

On the Motion of Protoplasm in the Fucaceous Algæ. By Professor P. Martin Duncan, *F.R.S.*

The Localization of Function in the Brain. By David Ferrier, *M.D., Professor of Forensic Medicine, King's College, London.*

In his paper on this subject, Dr. Ferrier alluded to the various theories at present held in regard to the possibility of localizing specific functions in definite regions of the brain—mentioning especially the various facts of disease, such as extensive abscesses, which appear to negative the idea of localization; and, on the other hand, those in favour of localization, such as the facts of aphasia, and the peculiar localized and unilateral epileptic and clonic spasms, which the researches of Hughlings Jackson seemed to connect with irritation of definite regions of the brain-centre.

The great difficulty had hitherto been the want of a method which would lead to positive results, instead of the usual negative phenomena resulting from the ordinary methods of investigating the functions of the brain by means of mechanical or similar destruction of the brain-substance. The researches of Fritsch and Hitzig and the theory of discharging lesions, advocated by Hughlings Jackson as the cause of the different epilepsies, formed the starting-point of the investigations which Dr. Ferrier communicated to the Association.

The results at which he arrived, from experimentation on the brains of rabbits, cats, and dogs, have already been partly published in the West-Riding Lunatic Asylum Report for 1873; but the experiments on monkeys and other animals, which were likewise brought before the Association, as well as the further elucidation of the experiments already published in the West-Riding Reports, are reserved for the Royal Society, under whose auspices the late experiments have been conducted. The following was the general scope of the paper The author, after a general sketch of the surface and convolutions of the brain in animals experimented on, pointed out on a series of diagrams the centres in the different convolutions, stimulation of which caused certain and unvarying combined movements of the paws and tail, of the facial muscles, and of the muscles concerned in articulation.

The homologous parts were pointed out in the brains of the rat, guineapig, rabbit, cat, dog, jackal, and monkey, and indicated in the human brain according to the convolutional homology existing between it and the simian brain.

In particular the complex movements of the hands and feet were described, and the situation of the centres of these various movements definitely localized. In addition to these centres for movements, which the author described as evidently volitional, purposive, or expressive, other regions of the brain, the posterior, were pointed out as probably the cerebral centres in connexion with some of the special senses, such as sight, hearing, and smell. On the same plan as before, the homologous parts and convolutions were indicated in the human brain.

Certain anterior regions at the frontal extremity of the cerebral hemispheres in the monkey, and also the posterior or occipital lobes of the monkey's brain, yielded no results which could yet be laid hold of.

A comparison was instituted between the corresponding parts in the brains of the lower animals and of man, and some speculations were offered as to the signification of the development of these parts in their relation to intelligence.

Several facts in relation to combined expressional movements, such as the mouth and hand, were shown to be dependent on the close cerebral relation of the centres for these movements, with powerful stimulation, one gradually radiating into the other.

The key to the psychological aspect of the facts presented by the experiment was indicated to be the condition of aphasia, which is usually found associated with disease of the posterior part of the inferior frontal convolution on the left side.

This region Dr. Ferrier showed, in the brain of the monkey, to be that part which governed the movements concerned in articulation; and the homology was also pointed out in the brains of the cat, dog, jackal, and other animals. Stimulation of this region in cats and dogs frequently elicited vocal speech in the form of mewing and barking; and it was the homologue of this part in the brain of man, disease of which was followed by the loss of articulate speech and the memory of words.

The two hemispheres of the brain, however, were shown to be symmetrical; and, in regard to the mouth, the action of the brain was also bilateral, and not, as usually the case, crossed and unilateral.

The explanation adopted was that the loss of the power of voluntarily recalling words was due to the fact of the left hemisphere being the leading side, just as in most people the right hand is most commonly used. The loss of speech was therefore due to the inability of the other side of the brain all at once to get at the proper word, even though they existed, as shown by the fact that the individual can recognize the word when mentioned.

The results of experiments on the hemispheres and optic lobes of fishes, frogs, and birds were also alluded to, but not entered into fully. The corpora striata were shown to be motor, and the optic thalami evidently sensory.

Curious effects were described as resulting from irritation of the corpora quadrigemina.

The cerebellum was shown to have a function not hitherto allotted to it, viz. the coordination of the ocular muscles. In the rabbit the various lobules were described as moving the eyes in different directions; and similar experiments with similar results had been obtained in the case of cats, dogs, and monkeys.

The relation of the cerebellum as an oculo-motorial and general equilibrium coordinating centre was slightly discussed, and their mutual interdependence indicated.

These latter subjects, however, are under investigation, as well as many other points in connexion with the cerebral hemispheres, and therefore the author contented himself with only a general sketch of the results.

Heart and Brain. *By* J. Milner Fothergill, *M.D., M.R.C.P.*

The qualities of endurance are rather cardiac than cerebral. Ability and determination bear no relation to each other; but the expressions "faint-hearted" and "stout-hearted" fall in with some of our most modern physiological views. When the blood-pressure on the brain is too great and the roots of the vagus (the restraining

nerve) are flooded with blood, the inhibitory fibres are thrown into action and the heart's contractions lowered. In hypertrophy of the heart the overgrown organ is not so readily reined in, and so apoplexy is commonly found along with this heart-change. In other cases, again, the blood-supply of the brain is defective, and then the brain is crippled. This was well seen in the case of a youth with congenital heart-disease, who came under the writer's notice, where the horizontal posture, so as to fill the head with blood, was necessary in order that the youth might learn or repeat his pieces of poetry. In medical practice the intimate association of heart and brain is well known, and in a large proportion of the cases of insanity distinct changes in the circulatory system are found. Where there is great cerebral hyperæmia, the ordeal bean of Calabar, which stimulates the inhibitory fibres of the vagus, and so holds back the heart, is found to be the most effective agent in controlling the violent mania of high cerebral vascularity. On the other hand, in cases of heart-disease the character commonly becomes altered, the resolute person becoming vacillating and capricious, the even-tempered person growing irritable and suspicious.' The effect of heart-disease on character is well seen in old Peter Featherstone in Middlemarch; and the vacillation of that obstinate old man betwixt his two wills shows how the brain halts and lacks its wonted determination when its arterial blood-supply is defective. The sensations of a patient in the great hospital of Vienna, whose heart stood still at intervals from the pressure of a tumour on the inhibitory nerve (the vagus), were described. Such is a part of the negative evidence of the relation of heart and brain: for the positive evidence we must turn to the records of the sporting world. Eclipse, the famous racer, and Master Magrath, the noted courser, two animals renowned for their tremendous endurance even more than for their speed, were both examined after death to see if any thing could be found to explain their peculiar prowess. In each an unusually large heart was found: and to this were attributed, and rightly so, their extraordinary powers. We may say, then, without hesitation, that a brain can no more give out efficient manifestations of force without a sufficient blood-supply, than an army can fight or manœuvre effectively without a proper commissariat, or an engine work up to its full power without a liberal supply of coal and water. Finally, we may conclude that the waves of nerve-force, which resolve themselves into either psychical resolution or sustained muscular effort, are dependent in their turn upon a well-maintained succession of blood-waves supplied by a firm and vigorous heart.

On the Physiological Action of Crystalline Aconitia and pseudo-Aconitia.
By Dr. Thomas R. Fraser.

The experiments were made with the nitrates of crystalline aconitia and pseudo-aconitia, prepared by Mr. Groves, F.C.S., who first separated aconitia in a crystalline form in 1864. Both alkaloids powerfully influence the cardiac contractions and respiratory movements. Their toxic power is very great, entitling them probably to be regarded as the most active poisons as yet known. A very remarkable and exceptional difference of toxicity for different species of animals was found to exist; for while aconitia is *for frogs* about five times more powerful as a toxic agent than pseudo-aconitia, the latter substance is *for rabbits* about twice as powerful as the former. It was ascertained that this difference depends on aconitia possessing a more energetic action on the heart, and a less energetic action on the respiratory movements, than pseudo-aconitia.

The Vocal Organs in Living Centenarians.
By Sir G. Duncan Gibb, *Bart., M.D., LL.D.*

The condition of the larynx and other vocal organs in persons who have reached the age of 100 years is of especial interest when determined during life, and presented some new facts necessitating a modification of the views generally entertained. The author's observations were founded upon an examination of nine living centenarians, whom he had personally visited in various parts of the country. Their names, residences, dates of examination, and authentic records of their births

were given, two being males and seven females; and although examined on but one occasion, the results were satisfactory, and less difficulty was experienced than was at first anticipated. The *thyroid cartilage* was more distinctly prominent in the two males than the females; in all nine it was freely movable, and not hard and unyielding, as is sometimes seen in persons of the age of 60 and 70. On slight compression there was a resiliency that pointed to cartilaginous flexibility, and lateral movements gave the sensation of cartilage gliding upon cartilage, showing absence of calcareous transformation in the articulating surfaces. The *hyoid bone*, readily felt in all, gave no enlargement or other alteration of the thyro-hyoid ligaments; nor were the pulsations of the carotids unduly felt, as occurs when their coats have become thickened by calcareous or other deposits. The *cricoid* cartilage on rotation gave the cartilaginous gliding already mentioned, and the rings of the *trachea* were compressible in any direction.

The laryngeal mirror had to be used with expedition, and revealed a vertical *epiglottis* in all, with its leaf-like expansion and light yellow colour, being thin towards the tip and sides, affording a ready view of the interior of the larynx. The *vocal cords* mostly formed a triangular glottis; they were longer in the males and in one of the females than in the others, whilst their colour in the latter was mostly of a greyish white: in one of the males it was yellow. The voice varied, being mostly smooth, soft, clear, and melodious; in the female with the long cords it was louder and more masculine than in the others, and so was it in one of the males, being at the same time somewhat cracked in tone. The chest capacity was fairly good in all, and the breathing of the most healthy character; the cartilages of the ribs were not ossified in any, for the movement of the ribs and their cartilages was wholly unimpeded, thus resembling persons of 25 or 30. Every organ in the body was normal, and the special senses as a rule were perfect. The conclusions arrived at were that there was an absence of these changes that are usually looked upon as senile, such as calcification of the laryngeal cartilages or of the coats of the blood-vessels, and ossification of the costal cartilages; and as all the organs and tissues of the body had undergone comparatively little or no change, persons over 95, or who reach the age of 100 years, must henceforth be considered to be free from such changes as are believed usually to bring life to a close between 70 and 80. As relates, however, to the epiglottis, its vertical position (the normal one) is common to all persons *over* the age of 70, as the author's researches have proved in an examination of 5000 healthy persons of both sexes and all ages; but the perfection of the cartilage is to be seen in centenarians.

White Corpuscles, their Nature and Origin in the Animal Organism. *By* Dr. J. Goodman.

In the prosecution of his experiments upon the development of fibrin by the action of water upon albuminous substance, the author discovered that sometimes instead of fibrin thousands of corpuscles presented themselves *.

The development of corpuscles was ultimately discovered to be the result of the employment of old eggs or of long-drawn serum, or, in other words, of albumen of low vital power, that from fresh albumen developing fibrin, that from old albumen corpuscles. A low temperature just above the freezing-point, even with fresh eggs, produced the same effect, and the substance thus formed was of lighter specific gravity than that which developed fibrin.

The exterior of the substance produced was discovered to form, generally under the influence of cold, a coating of a dark and coagulum-like material, sometimes enclosing well-formed fibrin, which, seen under the microscope by the reflected solar ray, was found to be constituted entirely of corpuscles. Thus corpuscles were seen to be produced in like manner with fibrin. When separate these little bodies always evinced a tendency to coalesce and unite together, and, like fibrin, thus to manifest a force of attraction, particle for particle, but in a minor degree. This power was greater or less in proportion to the degree of vital energy of the albumen employed.

* See a paper upon the origin of Fibrin in the Animal Organism, Proceedings of Sections, 1870, p. 139, and 1871, p. 72.

It was also proved, by frequently repeated experiment, that corpuscles by coalescing and uniting together develop fibrinous rods and other structures of this material. The substance thus formed, when subjected to compression between two plates of glass under the microscope, actually had its cohesive power overcome, and became resolved into corpuscles; and when the pressure was removed sometimes these again united, and developed fibrinous rods and other structures. Moreover corpuscles were the last products witnessed during the decomposition and disintegration of fibrin.

It was therefore rendered evident that corpuscles are identical in their nature with fibrinous substance, corpuscles and fibrin being mutually convertible into each other.

These two great coagulable and structure-forming components of the blood are thus seen to derive their origin from like substances, conditions, and agencies—viz. the subjection of albuminous material to the agency of water, both which ingredients are discovered in abundance in the lacteals and absorbents of the body.

As shown by some of our most eminent physiologists, excess of fibrin or of corpuscles in the human frame indicates a healthy or morbid state of the organism —the preponderance of fibrin being held by them as the symbol of the highest condition of health, whilst the predominance of corpuscles is equally maintained as indicative of a cachectic or otherwise unhealthy state of body: so in these experiments the corroborative voice of Nature declares that a high state of vitality in the albumen is associated with the development of fibrin, whilst a low vital energy in the substance employed has always a tendency to produce corpuscular products.

On the Mode of Formation of Renal Calculi.
By GEORGE HARLEY, *M.D., F.R.S., F.R.C.P.*

In this communication the author laid down several general laws as being applicable to all kinds of calculi, a few of which are the following:—

1st. Calculi may occur at every period of life from the cradle to the grave.

2nd. In all cases of constitutional concretions the amount of renal solids must be disproportionate to the amount of liquids excreted.

3rd. That the deposition of a calculus in any part of the renal system is in every case due to some special local cause. The cause may be trifling and temporary; but still it must exist. Once, however, the concretion has begun to form the original exciting cause is soon lost sight of, and the calculus goes on forming round its nucleus, quite independent of the local condition which called it into existence.

4th. The vast majority of constitutional calculi, be their nature what it may (oxalate of lime, phosphate of lime, uric acid, xanthin, or cystin), have their origin in the kidneys.

5th. The colour of the concretion does not always depend upon the nature of the substance which is composed, but upon the presence of other colouring-matters in the renal secretion. Uric acid calculi, for example, vary in depth of colour according as the quantity of urohæmatin is small or great; just as crystals of sugar-candy owe their pink, yellow, or other tints to the pigment present in the water out of which they are crystallized. Phosphatic and cystinic calculi form an exception to this rule by refusing to combine with extraneous pigments.

6th. There are three perfectly distinct modes in which crystalloid material is deposited in the formation of calculi.

The first and rarest form of calculi are those which consist of a monster crystal, or an aggregation of monster crystals, and are only to be met with in the case of triple phosphates, oxalate of lime, and uric acid. The second is that in which a certain amount of colloid is united with the crystalloid material; one in which it may be said that small crystals separating from the supersaturated renal secretion become entangled in mucus, tube casts, epithelium scales, or other colloid material, and by fresh aggregations around them gradually become closer and closer packed together, until they assume the appearance and properties of a compact concretion. The last mode of formation is by the aggregation of molecular atoms,

on the principle of molecular coalescence from the union of viscid or colloid material with earthy or organic crystalloid matter, in the manner of the formation of the dental tissues and shell-structures described by Mr. George Rainey.

To these three different modes of constitutional calculus formation the author gives the respective names of Crystalline, Crystallo-colloid, and Molecular coalescence. In concluding, the author remarked that the calculi he had been describing must not be confounded with those which, for the sake of distinction, might be termed "accidentally acquired," such as vesical, which frequently have for their nucleus foreign substances, such as a pea, a barleycorn, a piece of bone, hair, wire, a fragment of sealing-wax, or a portion of catheter, the irritation of which excites the presence of tenacious mucus, blood, or even pus, with which the foreign body itself becomes coated, and in and around which crystalloid molecules and actual crystals are deposited and form the calculus.

Lastly. Calculi are not always of uniform composition throughout. Their composition varies at different times with the different states of health of the patient. The centre of the concretion may be composed of uric acid, then may come a layer of oxalate of lime, and over that another layer of uric acid or of phosphate, so that in a section of a calculus the clinical phases through which a patient has past may be read as truthfully as the geologist can read the earth's history in the strata forming its crust.

On the Structure of the Egg, and the early Development of the Cephalopod Loligo. *By* E. Ray Lankester, *M.A., Exeter College, Oxford.*

The author discussed some points as to the nature and mode of formation of eggs, in connexion with his observations on the egg of the cuttlefish, *Loligo*. Every egg is originally a small corpuscle of protoplasm, like those which build up the tissues of animals; but it acquires additional substance, and in some animals (for instance, birds) becomes very large before it is laid. The additional substance differs in its character in different animals. In *Apus* four original egg-corpuscles fuse and form one egg, from which one embryo develops. In most cases the egg grows in the ovary by receiving nutrition from the blood; but in many cases (in birds, fishes, and in cuttlefish) the egg is contained in a capsule, which is lined with living corpuscles, and these are continually multiplying by division, and pass from the capsule into the egg to increase its bulk. This Mr. Lankester had demonstrated by sections in the case of *Loligo*. So far he agreed with Prof. His; but he did *not* find that these corpuscles remained alive and helped to form the embryo cuttle fish. The egg of *Loligo* when laid was a perfectly homogeneous mixture of albuminous matters of (*a*) the original egg-corpuscle, (*b*) the corpuscles from the capsule, and (*c*) the male spermatozoa. From this mixture there segregated at first to one pole plastic matter, which broke up into corpuscles ("klastoplasts") forming a cap (yelk-cleavage). Outside this cap of cleavage-corpuscles other large corpuscles ("autoplasts") then made their appearance by a new and independent process of segregation (free cell-formation); and these became branched, forming a deep or middle layer in the embryo, whilst the cleavage-corpuscles spread over them at a higher level.

Microzymes as partial Bionta. *By* Dr. John Ross.

Note on Huizinga's *Experiments on Abiogenesis.* *By* Dr. Burdon Sanderson.

Under the title of a "Contribution to the question of Abiogenesis," Prof. Huizinga has very recently published (Pflüger's Archiv, vol. vii. p. 549) a series of experiments which deserve notice, as constituting a new and carefully worked out attempt to support the doctrine of spontaneous generation.

Prof. Huizinga begins his paper with the words "Multa renascentur quæ jam cecidere," using them as an expression of the recurring nature of this question. He then proceeds to say that he was induced to undertake his inquiry by the publication of the well-known work by Dr. Bastian (whom he compliments as

having awakened the exhausted interest of physiologists in the subject), his special object being to repeat the much-discussed turnip-cheese experiment.

Every one knows what Dr. Bastian's observation is. It is simply this, viz. that if a glass flask is charged with a slightly alkaline infusion of turnip of sp. gr. 1015, to which a trace of cheese has been added, and is then subjected to ebullition for ten minutes and closed hermetically while boiling, and finally kept at fermentation temperature, *Bacteria* develop in it in the course of a few days. This experiment has been repeated by Huizinga with great care, and the accuracy of Dr. Bastian's statement of fact confirmed by him in every particular; yet, notwithstanding this, he thinks that the evidence afforded by these results in support of the doctrine so inadequate, that he, desiring to find such evidence, has thought it necessary to repeat the observation under what he regards as conditions of greater exactitude.

Huizinga's objections to Bastian's experiment are two. First, that when a flask is boiled and closed hermetically in ebullition, its contents are almost entirely deprived of air; and, secondly, that cheese is a substance of mixed and uncertain composition. To obviate the first of these objections he closes his flasks, after ten minutes' boiling, not by hermetically sealing them, but by placing over the mouth of each, while in ebullition, a porous porcelain plate which has first been removed from the flame of a Bunsen's lamp. The hot porcelain plate is made to adhere to the edge or lip of the flask by a layer of asphalt, with which the edge has been previously covered. The purpose of this arrangement is to allow air to enter the flask at the same time that all germinal matter is excluded. It is not necessary to discuss whether this is so or not.

To obviate the second objection he alters the composition of the liquid used; he substitutes for cheese, peptone: and for turnip-infusion, a mixture of the following composition in 1000 parts:—

Grape-sugar	25 grammes.
Potassium nitrate........	2 „
Magnesium sulphate	2 „
Calcium phosphate	0·4 gramme.

The phosphate is prepared by precipitating a solution of calcium chloride with ordinary sodium phosphate, taking care that the chloride is in excess. The precipitate of neutral phosphate so obtained is washed and then added to the saline solution in the proportion given. On boiling it is converted into soluble acid phosphate and insoluble basic salt, of which the latter is removed by infiltration; consequently the proportion of phosphate in solution is less than that above indicated. To the filtrate, peptone is added in the proportion of 0·4 per cent.

The peptone is obtained by digesting egg-albumen at the temperature of the body in artificial gastric juice, made by adding the proper quantity of glycerine extract of pepsin to water acidulated with hydrochloric acid. The liquid so obtained is first rendered alkaline by the addition of liquor sodæ, then slightly acidulated with acetic acid and boiled. The syntonin thus precipitated is separated by infiltration from the clear liquid, which is then evaporated to a sirup and poured in a thin stream into strong alcohol with constant agitation. The precipitated peptone is separated after some hours and washed with alcohol, and redissolved in a small quantity of water. The solution is again precipitated by pouring it into alcohol in the same way as before, and the precipitate washed and dried.

Flasks having been half filled with the liquid thus prepared (in 1000, two each of nitre and Epsom salts, a trace of phosphate of lime, twenty-five parts of grape-sugar, and four parts of peptone), each is boiled for ten minutes, closed while boiling with the earthenware plate as above described, and placed as soon as it is cool in the warm chamber at 30° C. The experiment so made gave, without any exception, a positive result in every case. After two or three days the fluid was crowded with actively moving *Bacterium termo*.

In June last I published in 'Nature' a repetition of Dr. Bastian's experiments, with a variation not of the liquid, but of the mode of heating. Instead of boiling the flasks for ten minutes over the open flame and closing them in ebullition, I boiled them, closed them hermetically, and then placed them in a digester, in

which they were subjected to ebullition under a pressure of 2 inches or more of mercury. The result was negative. There was no development of *Bacteria*.

Since the publication of these experiments Huizinga's have appeared. His result, regarded as a proof of spontaneous generation, is clearly not superior to Bastian's. His substitution of a soluble immediate principle for an insoluble mixed product like cheese, and the use of a definite solution of sugar and salts, are not material improvements. The question is not whether the germinal matter of *Bacteria* is present, but whether it is destroyed by the process of heating. Consequently what is necessary is not to alter the liquid, but to make the conditions of the experiment, as regards temperature, as exact as possible. In this respect Huizinga's experiment is a confirmation of Bastian's, and nothing more.

I have recently repeated Huizinga's experiments with the same modifications as regards temperature as those employed in my repetition of the turnip-cheese experiments. The result has been the same. In all essential respects I have followed the method described by him in his paper. I have prepared the solution of salts, grape-sugar, and peptone in exact accordance with his directions. To obviate his objection as to the absence of air, I have introduced the liquid, not into flasks, but into strong glass tubes closed hermetically at each end and only half filled with liquid, the remainder of the tube containing air at the ordinary tension. Each of these tubes, after having been subjected to the temperature of ebullition under 2 inches of mercury for half an hour, has been kept since September 10 at the temperature of fermentation (32° C.). Up to the time of my leaving London for Bradford no change whatever had taken place in the liquid.

As a control experiment I opened one of the tubes immediately after boiling, and introduced a drop of distilled water. It became opalescent in twenty-four hours.

On the Electrical Phenomena which accompany the Contractions of the Leaf of Dionæa muscipula. *By* Dr. Burdon Sanderson.

It is well known that in those structures in the higher animals which are endowed with the property of contracting when stimulated, viz. nerve and muscle, this property is associated with the existence of voltaic currents which have definite directions in the tissue. These currents have been the subject of very careful observation by physiologists. They require delicate instruments for their investigation, but the phenomena dependent on them admit of the application of the most exact measurements. The constant current which can be shown to exist in a muscle is called the normal current. The most important fact with reference to it is that it exists only so long as the muscle is alive, and that it ceases during the moment that the muscle is thrown into action. Other characteristics of the muscle-currents were referred to, which we have not space to mention.

In certain plants said to possess the property of irritability, contractions of certain organs on irritation occur which strikingly suggest a correspondence of function between them and the motor organs of animals. Among the most remarkable are those of *Drosera* and some other plants belonging to the same natural order, particularly the well-known Venus's Flytrap (*Dionæa muscipula*). The sensitive plant, the common monkey flower, the rock *Cistus*, afford other examples.

Strange as it may seem, the question whether these contractile movements are accompanied with the same electrical changes as those which occur in the contraction of muscle and in the functional excitation of nerve has never yet been investigated by vegetable physiologists. Mr. Darwin, who for many years has devoted much attention to the animal-like functions of *Dionæa* and *Drosera*, kindly furnished plants for the purpose of the necessary experiments, which have been made by Dr. Sanderson in the laboratory of University College, London. The result has been that the anticipations he had formed have been confirmed as to the existence of voltaic currents in these parts, and particularly in the leaf of *Dionæa*. By a most remarkable series of experiments, made with the aid of Sir W. Thomson's galvanometer, he has shown that these currents are subject, in all respects in which they have been as yet investigated, to the same laws as those of muscle and nerve.

On the Diverticulum of the Small Intestine in Man, considered as a Rudimentary Structure. By Professor C. A. Struthers.

On the Development of the Armadillo's Teeth. By C. S. Tomes.

Notes on the Anatomy and Physiology of the Indian Elephant. By Dr. Morrison Watson.

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Anthropology.

Address to the Department of Anthropology. By John Beddoe, *M.D., F.R.S.*

The position of Anthropology in the British Association, as a permanent department of the Section of Biology, being now fully assured, and its relations to the allied and contributory sciences beginning to be well understood and acknowledged, I have not thought it necessary, in opening the business of the department, to follow the example of my predecessors, Professor Turner and Colonel Lane Fox. The former of these gentlemen, at our Edinburgh Meeting, devoted his opening address to the definition, history, and boundaries of our science; the latter, at Brighton, in the elaborate essay which many of you must have listened to, not only discussed its relations to other sciences, but gave an illustrative survey of a great portion of its field and of several of its problems.

But while, on the one hand, I feel myself incompetent to follow these precedents with success, on the other I am encouraged to take a different line by the consideration that if, as we are fond of saying in this department, "the proper study of mankind is man"—if, that is, anthropology ought to interest every body, then assuredly the anthropology of Yorkshire ought to interest a Yorkshire audience.

Large as the county is, and sharply marked off into districts by striking diversities of geological structure, of climate, and of surface, there is an approach to unity in its political and ethnological history which could scarcely have been looked for. Nevertheless we must bear in mind the threefold division of the shire—not that into ridings, but that pointed out by nature. We have, first, the western third, the region of Carboniferous limestone and Millstone-grit, of narrow valleys and cold rainy moorlands; secondly, the great plain of York, the region, roughly speaking, of the Trias, monotonously fertile, and having no natural defence except its numerous rivers, which, indeed, have sometimes served rather as a gateway to the invader than as a bulwark against him; to this plain Holderness and the Vale of Pickering may be regarded as eastern adjuncts. Thirdly, we have the elevated region of the east, in the two very dissimilar divisions of the moorlands and the wolds; these are the most important parts of Yorkshire to the prehistoric archæologist, but to the modern ethnologist they are comparatively of little interest.

The relics of the palæolithic period, so abundant in the south of England, are, I believe, almost wholly wanting in Yorkshire, where archæology begins with the neolithic age, and owes its foundations to Canon Greenwell of Durham, Mr. Mortimer of Driffield, Mr. Atkinson of Danby, and their predecessors in the exploration of the barrows of Cleveland and the Wolds, whose results figure largely in the 'Crania Britannica' of Davis and Thurnam, themselves, by the way, both natives of the city of York.

The earliest inhabitants we can distinctly recognize were the builders of certain

long barrows, such as that of Scamridge in Cleveland. There is still, I believe, some difference of opinion among the anthropologists of East Yorkshire (where, by the way, in the town of Hull, the science flourishes under the auspices of a local Anthropological Society)—still, I say, some difference of opinion as to whether the long-barrow folk were racially diverse from those who succeeded them and who buried their dead in round barrows. But Canon Greenwell at least adheres to Thurnam's doctrine, and holds that Yorkshire, or part of it, was occupied at the period in question, perhaps 3000 years ago, by a people of moderate or rather short stature, with remarkably long and narrow heads, who were ignorant of metallurgy, who buried their dead under long ovoid barrows, with sanguinary rites, and who labour under strongly founded suspicions of cannibalism.

Of the subsequent period, generally known as the bronze age, the remains in Yorkshire, as elsewhere, are vastly more plentiful. The Wolds especially, and the Cleveland hills, abound with round barrows, in which either burnt or unburnt bodies have been interred, accompanied sometimes with weapons or ornaments of bronze, and still more often with flint arrow-heads. Where bones are found, the skull presents what Barnard Davis considers the typical British form; *i. e.* it is generally rather short and broad, of considerable capacity and development, with features harsh and bony. The bodily frame is usually tall and stalwart, the stature often exceeding 6 feet, as in the well-known instance of the noble savage of Gristhorpe, whose skeleton is preserved in the Scarborough Museum.

Though certain facts, such as the known use of iron in Britain before Cæsar's time and its extreme rarity in these barrows, and some little difference in proportion between the skulls just described and the type most common among our modern British Kelts, do certainly leave room for doubt, I have little hesitation in referring these round barrows to the Brigantes and Parisii*, the known occupants of Yorkshire before the Roman conquest.

Both what I will term provisionally the pure long-barrow and the pure round-barrow types of cranium are represented among our modern countrymen. But the former is extremely rare, while the latter is not uncommon. It is probable enough that the older type may, in amalgamating with the newer and more powerful one, have bequeathed to the Kelts of our own time the rather elongated form which prevails among them. Whether this same older type was really Iberian is a point of great interest, not yet ripe for determination.

Another moot point is the extent to which the population of modern England is derived from the colonists introduced under the Roman occupation. It is my own impression that the extent, or rather the intensity of such colonization, has been overestimated by my friend Mr. Thomas Wright and his disciples. I take it that, in this respect, the Roman occupation of Britain was somewhere between our own occupations of India and of South Africa, or perhaps still more nearly like that of Algeria by the French, who have their roads, villas, and military establishments, and even considerable communities in some of the towns, but who constitute but a very small percentage of the population, and whose traces would almost disappear in a few generations, could the communication with the mother country be cut off.

If, however, any traces of the blood of the lordly Romans themselves, or of that more numerous and heterogeneous mass of people whom they introduced as legionaries, auxiliaries, or colonists, are yet recognizable anywhere in this county, it may probably be in the city of York, or in the neighbourhood of Catterick. The size and splendour of ancient Eburacum, its occupation at various times as a sort of military capital by the Emperor Severus and others, its continued existence through the Anglian and Anglo-Danish periods, and its subsequent comparative freedom from such great calamities† or vicissitudes as are apt to cause great and sudden changes of population, might almost induce us to expect to find such vestiges. If Greek and Gothic blood still assert themselves in the features and figures of the people of Arles, if Spanish characteristics are still recognizable in Bruges, why not Italian ones in York? It may be so; but I must confess that I have not seen

* It has been conjectured that the Parisii were Frisians; but I think it very unlikely.

† Unless, indeed, York was the "municipal town" occupied by Cadwalla, and besieged by his Anglian adversaries.

them, or have failed to recognize them. Catterick, the site of ancient Cataractonium, I have not visited.

Of the Anglian conquest of Yorkshire we know very little, except that it was accomplished gradually by successive efforts, that the little district of Elmet, in the neighbourhood of Leeds, continued British for a while, and that Carnoban (which is almost certainly Craven) is spoken of by a Welsh writer as British after all the rest of the country had ceased to be so—a statement probable enough in itself, and apparently corroborated by the survival of a larger number of Keltic words in the dialect of Craven than in the speech of other parts of Yorkshire.

Certain regulations and expressions in the Northumbrian laws (among others the less value of a churl's life as compared with that of a thane) have been thought to indicate that the proportion of the British population that remained attached to the soil, under Anglian lords, was larger in the north than in some other parts of England. The premises are, however, insufficient to support the conclusion; and, on the other hand, we are told positively by Bede that Ethelfrith Fleisawr drove out the British inhabitants of extensive districts. The singular discoveries of Boyd Dawkins and his coadjutors in the Settle Cave, where elaborate ornaments and enamels of Romano-British type are found in conjunction with indications of a squalid and miserable mode of life long endured, attest clearly the calamities of the natives about that period (the early part of the seventh century), and show that even the remote dales of Craven, the least Anglian part of Yorkshire, afforded no secure refuge to the Britons of the plains, the unfortunate heirs of Roman civilization and Roman weakness. The evidence yielded by local names does not differ much from that of the same kind in other parts of England. It proves that enow of Welshmen survived to transmit their names of the principal natural features (as Ouse, Derwent, Wharfe, Dun, Roseberry, Pen-y-gent), and of certain towns and villages (as York, Catterick, Beverley, and Ilkley), but not enow to hinder the speedy adoption of the new language, the renaming of many settlements, and the formation of more new ones with Anglian names. The subsequent Danish invasion slightly complicated this matter; but I think it is pretty safe to say that the changes in Yorkshire were more nearly universal than in counties like Devonshire, where we know that the descendants of the Welsh constitute the majority. If the names of the rivers Swale and Hull be really Teutonic, as Greta undoubtedly is, the fact is significant: for no stream of equal magnitude with the Swale, in the south of England, has lost its Keltic appellation.

We do not know much of the Anglian type, as distinguished from the Scandinavian one which ultimately overlaid it almost everywhere to a greater or less depth. The cranial form, if one may judge of it by the skulls found in the ancient cemetery of Lamel Hill near York, was not remarkably fine, certainly not superior to the ancient British type as known to us, to which, moreover, it was rather inferior in capacity. There is some resemblance between these Lamel-Hill crania and the Belair or Burgundian type of Switzerland; while the Sion or Helvetian type of that country bears some likeness to our own Keltic form.

The group of tumuli called the Danes' Graves, lying near Driffield, and described by Canon Greenwell in the 'Archæological Journal', have yielded contents which are a puzzle for anthropologists. Their date is subsequent to the introduction of the use of iron. Their tenants were evidently not Christians; but they belonged to a settled population. The mode of interment resembles nothing Scandinavian; and the form of the crania is narrower than usual, at least in modern times, in Norway and Denmark. It is hazardous to conjecture any thing about them; but I should be more disposed to refer them to an early Anglian or Frisian settlement than to a Danish one.

We come now to the Danish invasions and conquest, which, as well as the Norman one that followed, was of more ethnological importance in Yorkshire than in most other parts of England. The political history of Deira from the ninth century to the eleventh, the great number of Scandinavian local names (not greater, however, in Yorkshire than in Lincolnshire), and the peculiarities of the local dialect, indicate that Danes and Norwegians arrived and settled, from time to time, in considerable numbers. But in estimating those numbers we must make allowance for their energy and audacity, as well as for the very near kinship

between the Danes and the Northumbrian Angles, which, though it did not prevent sanguinary struggles between them at first and great destruction of life, must have made amalgamation easy, and led the natives readily to adopt some of the characteristics of the invaders.

Whatever the Danish element in Yorkshire was, it was common to Lincolnshire and Nottinghamshire and to the north-eastern part of Norfolk, and it was comparatively weak in Northumberland and even in Durham. In Yorkshire itself it was irregularly distributed, the local names in *by*, *toft*, and *thwaite* and the like being scattered in a more or less patchy manner, as may be seen on Mr. Taylor's map. They are very prevalent in Cleveland, as has been shown by Mr. Atkinson. Again, the long list of the landowners of the county under Edward the Confessor, given in Domesday book, contains a mixture of Anglian with Scandinavian names, the latter not everywhere preponderating. Here, again, Cleveland comes out very Danish. I am inclined to believe that the Anglian population was, in the first fury of the invasion, to some extent pushed westwards into the hill-country of the West Riding, though even here distinctly Danish names, such as Sowerby, are quite common. Beverley and Holderness perhaps remained mainly Anglian.

The Norman conquest fell upon Yorkshire, and parts of Lancashire and Durham, with unexampled severity. It would seem that the statement of William of Malmesbury, that the land lay waste for many years through the length of 60 miles, was hardly, if at all, exaggerated. The thoroughness and the fatal effects of this frightful devastation were due, no doubt, partly to the character of William, who, having once conceived the design, carried it out with as much completeness and regularity as ferocity, and partly to the nature of the country, the most populous portion of which was level and devoid of natural fastnesses or refuge—but also, in some degree to the fact that the Northumbrians had arrived at a stage of material civilization at which such a mode of warfare would be much more formidable than while they were in a more barbarous condition, always prepared for fire and sword, and living, as it were, from hand to mouth. Long ages afterwards the Scots told Froissart's informants that they could afford to despise the incursions of the English, who could do them little harm beyond burning their houses, which they could soon build up again with sticks and turf; but the unhappy Northumbrians were already beyond that stage.

In all Yorkshire, including parts of Lancashire, Westmoreland, and Cumberland, Domesday numbers only about 500 freemen, and not 10,000 men altogether. This great destruction, or rather loss of population (for it was due in some measure to the free or forced emigration to Scotland of the vanquished), did not necessarily imply ethnological change. Let us examine the evidence of Domesday on this point. It agrees with that of William of Malmesbury, that the void created by devastation remained a void, either entirely or to a great extent. Whole parishes and districts are returned as "waste." In one instance 116 freemen (sockmanni) are recorded to have held land in King Edward's time, of whom not one remained; in another, of 108 sokemen only 7 remained. But foreigners *did* settle in the county to some extent, either as military retainers of the new Norman lords, as their tenants, or as burgesses in the city of York, where 145 francigenæ (Frenchmen) are recorded as inhabiting houses.

Of the number maintained by way of garrisons by the new nobility, one can form no estimate; but considering the impoverished and helpless condition of the surviving natives, such garrisons would probably not be large. But from the enumeration of mesne tenants, or middlemen, some inferences may perhaps be drawn. On six great estates, comprising the larger part of Eastern and Central Yorkshire, sixty-eight of these tenants are mentioned by name, besides 11 milites, or men-at-arms. Only 11 of the 68 bear names undoubtedly English; and none of them have large holdings, as is the case with some of those bearing Norman names. On the lands of Drogo de Bevrere, about Holderness, several of the new settlers were apparently Flemings.

The western part of the county, however, or the greater part of it, had been granted to two lords who pursued a more generous policy. Alan, count of Bretagne, the founder of Richmond, had twenty-three tenants, besides twelve milites, men-

at-arms with very small holdings. Of the twenty-three, nine were Englishmen, in several instances holding as dependents the whole or part of what had been their own freeholds. The Breton ballads and traditions seem to favour the supposition that Count Alan's Breton followers mostly returned home; and Count Hersart de la Villemarquée, the well-known Breton archæologist, informed me that his ancestors returned to Bretagne from Yorkshire in the twelfth century. On the whole, I do not think it probable that the Breton colony was numerous enough to leave distinct and permanent vestiges; but if any such there are, they may be looked for in the modern inhabitants of Richmond and Gilling.

Ilbert de Lacy, again, had a great domain, including most part of the wapentakes of Morley, Agbrigg, Skyrack, and Staincross—extending, that is, far to the north and south of our present place of meeting. Bradford, by the way, was then hardly so important and wealthy as at the present day. A thane named Gamel had held it in the time of Edward the Confessor, when it was valued at four pounds yearly; but at the time of the survey it was waste and worth nothing.

Sixty-seven mesne tenants under Ilbert de Lacy are mentioned, of whom no less than forty-one bore English names, and only twenty-six foreign ones. It is probable therefore that in this important part of the county the ethnological change wrought by the Conquest was not greater, if so great as in England generally, but that in the centre, east, and north-east it was of some moment, and that the Scandinavian element of population suffered and lost more than the Anglian.

It might be a matter of some interest to a minute ethnologist or antiquarian to trace out fully the local history after the Conquest from an ethnological point of view, investigating particularly the manner and source of the repeopling of the great plain of York.

After this had been completed, no further change of ethnological importance took place during several centuries. The Flemings and Frisians, who, in considerable numbers, settled at various times in Leeds, Halifax, and Wakefield, whether drawn hither by the course and opportunities of trade, or driven by the persecutions of Philip II. and the Roman Catholics, brought in no new element, and readily amalgamated with the kindred race they found here.

The more recent immigrations into the West Riding and Cleveland from all parts of Britain, and even from the continent of Europe, have interest of other kinds. Vast as they have been, they have not yet obscured in any great degree the local types, physical or moral, which still predominate almost everywhere, though tending of course to assimilate themselves to those of the mixed population of England in general.

In describing these types I prefer to use the words of Professor Phillips, who, in his 'Rivers of Yorkshire,' has drawn them in true and vivid colours. He speaks of three natural groups:—

"First. Tall, large-boned, muscular persons; visage long, angular; complexion fair or florid; eyes blue or grey; hair light, brown or reddish. Such persons in all parts of the county form a considerable part of the population. In the North Riding, from the eastern coast to the western mountains, they are plentiful.

"Second. Person robust; visage oval, full and rounded; nose often slightly aquiline; complexion somewhat embrowned, florid; eyes brown or grey; hair brown or reddish. In the West Riding, especially in the elevated districts, very powerful men have these characters.

"Third. Person of lower stature and smaller proportions; visage short, rounded; complexion embrowned; eyes very dark, elongated; hair very dark. Individuals having these characters occur in the lower grounds of Yorkshire, as in the valley of the Aire below Leeds, in the vale of the Derwent, and the level regions south of York."

I have chosen to quote from Professor Phillips rather than to give descriptions of my own, both because his acquaintance with the facts is more extensive than mine, and because I desire to pay my small tribute to the genius and insight of the author of a work so unique and so admirable as his upon Yorkshire.

He ascribes the first and second of these types mainly to a Scandinavian, the last to a Romano-British, or possibly Iberian origin; and appears to think that the first, the tall, fair, long-faced breed, resembles the Swedes, and that the second,

the brown burly breed of the West Riding, is more Norwegian in character. He probably selects the Swedes as the purest or most typical of the Scandinavian nations. For my own part, I am disposed to treat the first as Norwegian more than Anglian, the second as Anglian rather than Norse, and Norse rather than British. The tall fair type engrosses most of the beauty of the north, having often an oval face, with a fine straight profile nearly approaching the Greek, as Knox and Barnard Davis, two close observers, have both remarked. And it is markworthy that it reappears in force almost everywhere in Britain where Norse blood abounds, *e.g.* in Shetland, Orkney, Caithness, in the upper class of the Hebrideans, in Cumberland, Westmoreland, and Lonsdale, about Lincoln (where Professor Phillips also noted it) and the Vale of Trent, and about the towns of Waterford and Wexford. The second type, on the other hand, much resembles a prevailing form in Staffordshire, a very Anglian county. A notable point about it is the frequency of eyes of a neutral undecided tint, between light and dark, green, brown, and grey, the hair being comparatively light. The third is of more doubtful and of more manifold origin. Iberian, Britokeltic, Roman, Breton, Frenchman, may all or any of them have contributed to its prevalence. I am inclined to think, though on rather slender grounds, that it is common in some of the districts depopulated by the Conqueror. Professor Phillips speaks of its smaller proportions; but it includes many robust men. It is probably far from well representing the Brigantian type, which seems to me to have influenced the other types, but rarely to crop out at all purely.

The breadth of the head is on the average somewhat greater in Yorkshire than in other parts of Britain; so we are informed by the hatters. In this the natives of Yorkshire agree with those of Denmark and Norway, who have rather broader heads than those of Sweden and Friesland.

I have already spoken of the colours of the eyes and hair. The latter is on the whole lighter in Yorkshire than in most parts of England; but dull rather than bright shades prevail. In the east, at Whitby, Bridlington, and Beverley, in Teesdale and Middle Airedale, light hair is particularly abundant; in Craven, as might have been expected, it is less so: other parts of the county are not so well known to me; and in this matter I have to trust to my own observation.

As to the stature and bulk of the people, however, I have much and accurate information, through the kindness of numerous observers, some of them of repute as naturalists. These are Mr. Atkinson of Danby, Mr. Tudor of Kirkdale, Dr. Wright of Melton, Dr. Christy of the North Riding Asylum, Drs. Kelburne King and Casson of Hull, Mr. Ellerton of Middlesborough, Mr. Wood of Richmond, Mr. Kaye of Bentham, Mr. Edy of Grassington, Dr. Paley of Ripon, Dr. Ingham of Haworth, Messrs. Armitage of Farnley, Dr. Wood of Kirkby Overblow, Dr. Aveling and Mr. Short of Sheffield, Mr. Milner, late of Wakefield Prison, and a clergyman on the Wolds, whom the prejudices or fears of his parishioners will not allow me to name. "A Yorkshireman," complained this last gentleman, "is a difficult animal to catch and weigh and measure;" but a very large number of them have been subjected to these processes by my obliging correspondents. The general result is that in the rural districts they are remarkably tall and stalwart, though not, except in parts of the west, so heavy as their apparent size would indicate—but that in the towns, and especially in Sheffield, they are rapidly degenerating; and I conclude from the Haworth report that the same is the case in the manufacturing villages. In many of the rural districts the average ranges between 5 feet 8 and 5 feet 9 inches, and about Richmond and on the Bentham Fells is considerably higher; while at Sheffield, and even at Haworth, it may hardly reach 5 feet 6 inches. The causes of this great degeneration are manifold: some of them may easily be traced; but either the will or the power to remedy the evil is wanting.

Of the moral and intellectual endowments of Yorkshiremen, it may perhaps appear presumptuous or invidious to speak; but the subject is too interesting to be passed by in silence, and I will endeavour to treat it without either "extenuating, or setting down aught in malice." In few parts of Britain does there exist a more clearly marked moral type. To that of the Irish it has hardly any affinity; but the Scotchman and the Southern Englishman alike recognize the differences which distinguish the Yorkshire character from their own, but are not so apt to appre-

ciate the numerous respective points of resemblance. The character is essentially Teutonic, including the shrewdness, the truthfulness without candour, the perseverance, energy, and industry of the Scotch, but little of their frugality, or of the theological instinct common to the Welsh and Scotch, or of the imaginative genius, or the more brilliant qualities which sometimes light up the Scottish character.

The sound judgment, the spirit of fair-play, the love of comfort, order, and cleanliness, and the fondness for heavy feeding are shared with the Saxon Englishman; but some of them are still more strongly marked in the Yorkshireman, as is also the bluff independence—a very fine quality when it does not degenerate into selfish rudeness. The aptitude for music was remarked by Giraldus Cambrensis seven centuries ago; and the taste for horseflesh seems to have descended from the old Norsemen, though it may have been fostered by local circumstances. The mind, like the body, is generally very vigorous and energetic, and extremely well adapted to commercial and industrial pursuits, as well as to the cultivation of the exact sciences; but a certain defect in imaginative power must, I think, be admitted, and is probably one reason, though obviously not the only one, why Yorkshire, until quite modern times, was generally behindhand in politics and religion, and why the number of her sons who, since Cædmon, have attained to high eminence in literature is not above the average of England.

Note on the Iberians. By John Beddoe, *M.D., F.R.S.*

The writer briefly adverted to:—1st. The longer heads and more frequently light hair of the Spanish Basques as compared with the modern Aquitanians. 2ndly. The probable presence in Aquitaine of a melanochroic element of population, neither Basque, Kymric, nor Gaelic, but possibly Ligurian. 3rdly. The presence of a common element in the populations of the Basque countries, of Bretagne, and of Wales, indicated by certain physical types.

The Serpent in connexion with Primitive Metallurgy. By A. W. Buckland.

In considering the innumerable serpent legends which have descended to us from an immeasurable antiquity, we cannot fail to be struck with the remarkable fact that by far the larger number represent the serpent either as the guardian of hidden treasure and revealer of hidden knowledge, or as in some way connected with gold and gems. Pursuing our inquiries further, we find almost invariably that all the heroes and gods with whom the serpent is associated are also credited with some mysterious power over riches, agriculture, and atmospheric phenomena: they are always the pioneers of civilization, the teachers of agriculture and of mining: their age is the golden age of the people over whom they reign; and in all these instances the serpent is the Agathodæmon, the good and benevolent deity, sometimes the creator, almost always the first and oldest of gods or demigods, and in this character is generally accompanied by an egg as an emblem of the world, or a cone symbolical of the sun or fire, these serpent races being invariably worshippers of the sun and earth. But we find that this character of the serpent is confined to Turanian races, or to those nations who have at some time or other passed under Turanian influences. Among the Aryans and Semites the serpent is looked upon as a form of evil, although this idea is modified in many cases by a survival of primitive belief, so that in Hindostan he is still regarded with veneration, although the origin of that veneration can generally be traced to aboriginal tribes. It would therefore appear that the serpent may yet become a very important ethnological guide; and being traced back to the age of totemism, and read by the light of legends confirmed by early monuments, it may probably be assumed that the primitive tribe or tribes bearing the serpent as a totem were also the first metal workers, and had acquired their knowledge of metals in some way through the instrumentality of the totem, for this reason so highly and so widely venerated. It would also appear that these early serpent

tribes carried their knowledge from the parent hive (probably in Central Asia or India, where the precious metals abound) across Asia, Africa, Europe, and even to America, leaving traces of their presence everywhere in serpent symbols, serpent mounds, megalithic monuments, and the earliest traces of metallurgy, confined, however, to the use of the three precious metals in their pure unsmelted form. And it would further appear that the connexion with America was broken before smelted metals and iron became known, the art of smelting having probably been an accidental discovery of the Aryan successors of the early serpent tribes. This serpentine origin of metallurgy the author has endeavoured to set forth at some length in this paper, believing it to be a matter worthy of further investigation, being apparently confirmed by the present veneration of the serpent existing among Turanian races, and the absence of serpent traditions among savages living in a purely stone age, excepting in the Fiji Islands, where the inhabitants bear traces of great admixture with Asiatic tribes.

Observations on Professor Gennarelli's *Paper "On the Existence of a Race of Red Men in Northern Africa and Southern Europe in Prehistoric Times." By* C. H. E. Carmichael, *M.A.*

This communication gave an analysis of a paper recently read before the Anthropological and Ethnological Society of Italy by Prof. Gennarelli. The arguments adduced rest partly on the exposition of various myths, and partly on so-called historical evidence furnished by the hieroglyphics of Egypt and the pottery of Etruria, where representations of men are coloured red, and those of women of a lighter shade. As a consequence of the discussion of Gennarelli's hypothesis, an Italian Committee has been formed for the study of the primitive races of Italy.

On Prehistoric Names of Weapons. By Hyde Clarke.

This was a first attempt to apply the evidence of philological science to the consideration of the distribution of the names of weapons in illustration of the distribution of the weapons themselves among various races. Examples were taken from the Indian region, West Africa, North America, South America, and Australia, of the roots BK, BN, KN, and DM, applied to *arrow* and *dart*, *knife*, *axe* or *hatchet*, *spear* or *lance*. Of one of these an example was given in Naga (India) of *kipi* and *takoaba*, and in Houssa (Africa) of *kebia* and *takobi*. In the latter triliteral epoch, the fanciful reference of weapons to the tongue as darting was mentioned in *degen* and *tongue*, *lancea* and *lingua*, *gladius* and *glotta*. Examples were also given from Australia.

On the Comparative Chronology of the Migrations of Man in America in relation to Comparative Philology. By Hyde Clarke.

The object of this paper is to show that, so far as the evidence of language is as yet available and so far as probabilities go, the languages and culture of America are connected with those of the Old World, and that there is no exclusive or indigenous American language, grammar, or culture. The inference drawn is that there is an original community of races and of culture, but that the culture was arrested in its development by the stoppage of migration of the advanced races. Successive migrations are declared to represent successive geological formations, and the essay is made to lay the foundation of the comparative chronology of man. The earliest migration determined by philology is that of the three languages of the Negritos or Pygmeans, allied to the Mincopies of the Andamans. To the austral branch are assigned the Natchez and Muskogulge, or Creek of North America, the Alikulip and Tekeenika of Tierra del Fuego; to the septentrional belong the North-American Shoshoni, Utah, Comanch, &c., the Netela and Kij, the Central American Bayano and Darien, and the South-American Mayoruna and Kiriri; and to the polar the Eskimo.

To the Lenca of Honduras are joined the Coretu of South America as allied to

the Kouri of West Africa. The great Carib group is connected with those of Dahomey and Whydah.

The close connexion of the Guarani and Omagua with the Abhass of Caucasia and the Agaw of the Nile, in grammar and roots, embraces the Guarani, Tupi, Om-agua, Mundrucu, Apiaca of Brazil, the Movima Saraveca &c. of the Missions, the S. Pedro and Coretu of the Orinoco. More distant are the Skwali, Sekumne, and Tsamak of California.

The want of better knowledge was accounted for by imperfect information as to the languages of the Old and the New World, and by the disappearance of whole formations of languages, leaving only surviving a few detached and ill-connected members, much altered by subsequent influences.

A tradition of the Americas and Australia was attributed to the Greek, Roman, and mediæval geographers.

On the Ashantee and Fantee Languages. By Hyde Clarke.

These, together with the Dzellana, were classified with the Korean and the Chetemachs assigned as a North-American branch. It was noted, in reference to the common origin of culture, that the Oricas had, like the Ashantees, established a large kingdom and repulsed European forces.

On the Report concerning Bushman researches of Dr. W. H. Bleek, Ph.D. By Hyde Clarke.

Dr. Bleek had been supplied by the authorities of the Cape of Good Hope with a large number of Bushmen convicts. From these he had written down more than four thousand columns (half pages quarto) of text, besides a dozen genealogical tables, and other genealogical, geographical, pathological, &c. notices. An English-Bushman vocabulary of 142 pages and a Bushman-English one of 600 pages have been formed. The mythology in which animals and heavenly objects are personified is largely illustrated. It is expected that the Cape legislature will authorize the publication of these important materials for anthropological investigations.

On the Northern Range of the Iberians in Europe. By W. Boyd Dawkins, *M.A., F.R.S.*

The range of the Iberian Basque, or Euskarian peoples, characterized by their small stature, dark complexion, jet-black hair and eyes, oval face, and orthognathic skull, was examined from the point of view offered by history. In the earliest records the population of the Iberic peninsula was composed of two elements, the northern, to which its name is due, and the southern or Celtic, the fusion between the two being proved by the name Celtiberi, or Castilians. In France, at the time of the conquest by the Romans, the Iberic element was represented by the Aquitani in the region bounded by the Garonne and Gironde, but whose north-eastern frontier was subsequently extended to the Loire (Ligur). Between them and the allied Ligurian tribes on the borders of the Mediterranean a broad band of Celtæ interposed, marking that the eastern Pyrenees was the route by which the Celtic invasion of Spain took place. The Belgæ pressed on the Celtæ, occupying the valley of the Rhine. The same sequence of peoples was maintained in Britain. In the west of Wales the Iberians were represented by the Silures; the Celtæ occupied the greater part of the island, and the Belgæ had taken possession of the maritime region. The dark-haired inhabitants of South-west Ireland were of Iberian descent, and the Celtæ possessed most of the island. These "ethnological islands" of Iberians, in Ireland, in Wales, in South-east France, and it may be added in Sicily, isolated by a sea of Celt from the mainland of Basques, proved that the Iberic peoples were once distributed through the area under consideration *before* the Celtæ had driven them away to the west.

This conclusion is confirmed by an examination of the contents of ossiferous caves and of tumuli, by which they were shown to have extended as far north

as Oban, and as far to the east as Belgium in the Neolith age, the human remains described by himself, Busk, Thurnam, Broca, Dupont, and others being of the same type as those from Basque cemeteries in the museum of the Anthropological Society of Paris, and the associated works of art being for the most part the same. The caves of the Iberic peninsula were also occupied by Basques in the neolithic stage of culture.

The Basque population was probably derived from Asia, and the route by which they passed into Europe was probably the same as that by which the Celtæ, Belgæ, and Germans advanced to the west rather than by way of Africa. It is also very likely that the Basques stood in close relation to their neighbours the Etruscan, and the two non-Aryan peoples may have been identical in race, related to each other as Celt to Belgian.

Some Remarks on Ethnic Psychology. *By* ROBERT DUNN, *F.R.C.S.*

The comparative psychology of the typical races of man presents a subject for investigation of great interest to many an ethnological inquirer and to all physiological anthropologists, but at the same time is of a character so wide and comprehensive, that the author confines his remarks principally to the physiological bearings of the subject—to cerebral psychology. He observes that, while comparative psychology, in its widest sense, embraces the study and strict interpretation of all those living experiments (to use the happy expression of Cuvier) which nature presents to us in an ascending series in the wide domain of animal life, from the lowest up to man himself, ethnic psychology restricts the inquiry to the genus *Homo sapiens* and its typical varieties. He refers to a paper which he read at the Cambridge Meeting of the British Association in 1862, "On the Psychological Differences which exist among the Typical Races of Man," in which he dwelt upon the importance of carefully studying and of contrasting and comparing the cerebral organizations of the typical races, with the view, and as the most efficient means, to the better understanding and elucidation of the psychological differences which exist among and characterize them. Believing as he then did, and as he still does, that the distinctive psychical differences which exist among the typical races will be found to be engraven on their brains, he here again enforces the paramount importance of this duty, and indicates a field of investigation and inquiry which, if fully explored, cannot fail, as he thinks and believes, of throwing a flood of light upon the subject of ethnic psychology. He dwells on the labours of Gratiolet in France, quoting the emphatic language of Professor Rolleston, of Oxford, "what Max Müller had done for language and Adams for astronomy, that Gratiolet had done for the anatomy of the brain; " regretting at the same time that, notwithstanding the labours of Gratiolet and the chart which he may be said to have provided for our guidance as a standard of comparison, the brains of the typical races have yet to be carefully examined, compared, and contrasted with each other. This remains to be done, and is still a *desideratum.* He strives to impress *strongly* on the minds of others his own *conviction* of the necessity and importance of a more exact knowledge than that to which we have yet attained of the cerebral structural differences which exist among the typical races. The *basis* of his own conviction of the paramount importance of the duty of studying, contrasting, and comparing in all the different races the nervous apparatus and organic instrumentality through which their varying psychological phenomena are manifested, rests on the postulates that the genus *Homo is one,* and that the *brain is the instrument of the mind*; and on the consequent and legitimate corollary from these, that the distinguishing psychical differences which exist among the typical races are greatly, if not altogether, dependent upon structural differences in their cerebral organizations. He says all physiological psychologists are agreed that the vesicular matter of the great hemispherical ganglia of the brain is the *sole* and *exclusive seat* of all intellectual action and volitional power, but that his own mind rests in the conviction, as a well-established fact, that different parts and portions of the vesicular matter of the cerebral hemispheres are the seat of special psychological activities and of different kinds of mental action. He says the type of the brain is the same in all the different races, and that in its evolution and ascensive development it passes through the

phases in which it appears in the Negro, Malay, American, and Mongolian races, and finally reaches the highest or Caucasian type; so that, in fact, the leading characters of the typical races of mankind are virtually and simply representations of particular stages of the highest or Caucasian race. As the anterior lobes of the brain are the seat of the intellectual activities, fullness of development and complexity of structure are sure indications of the elevation of the racial type; while, on the other hand, the converse, as seen in the Negro or Bushman, is equally true, viz. that simplicity of structure and perfect symmetry of type and arrangement of the convolutions on both sides of the hemispheres are indisputable marks of degradation of function and inferiority of race. He says Gratiolet has dwelt on the importance of studying with scrupulous care and attention the complexities, relations, and arrangements of the convolutions on the inferior, frontal, and coronal stage in all the typical races, with a view to their psychical significance, and to the elucidation and advancement of the study of ethnic psychology. In conclusion, he says that the fact is indisputable that the large-brained European differs from and far surpasses the small-brained savage in the complexity of his manifestations, both intellectual and moral; but then he asks, Is not all this in strict accordance with and what *à priori* might be expected to result from *organic differences* in the instruments of the higher psychical activities—in other words, in the nervous apparatus of the perceptive and intellectual consciousness?

Notes on Coral-Caves with Human Bones in Stalagmite on Mangaia, South Pacific. By the Rev. W. Wyatt Gill, *B.A.*

The author has resided for many years on the little island of Mangaia, one of the seven islands constituting the Hervey group. Mangaia is in 21° 57′ south latitude, and 158° 7′ west longitude. It is nearly 20 miles in circumference, and not more than 800 feet above the sea-level, with an unbroken fringing reef. The interior of the island is formed of dark volcanic rock, rising in low hills striking from a single flat-topped centre. There is no lagoon. Streams of water from the centre portion, after fertilizing some thousands of taro-plantations, find their way to the ocean through a remarkable belt of uplifted dead coral, which, like a cyclopean wall, surrounds the inner part of the island. This mass of coral rock begins to rise gradually about 300 yards from the rugged beach and slopes up to a ridge, but towards the interior is perpendicular. It is from one to two miles across. In some places the surface bristles with jagged rock sharp as spear-points. Many are the ghastly wounds to the passenger occasioned by footslips. Numerous sea-shells, similar to those on the present beach, are imbedded in this reef, even in the highest parts. It is everywhere perforated by caverns and galleries. Mangaia thus remarkably displays both the ordinary forms of coral islands, the reef of dead coral upraised on the land, and the fringing reef at sea denoting elevation first and then subsidence—both requiring a very long period of time for growth. The caves in the dead coral have been used as habitations, as refuges, and as cemeteries. Scores of them are filled with desiccated human bodies; stalactite and stalagmite abound, and form thick and fast-growing layers of limestone rock, of which the author exhibited some specimens. In the waters lying in the hollows were numerous limestone balls.

Soon after arriving in Mangaia in 1852, the author explored a great number of caverns on the southern part of the island. The great "cave of Tevaki" divides into two branches—the one communicating with the sea, the other with a glittering stalactite roof terminates in an awful chasm. Pursuit of a tribe entrenched in such a natural fortress was out of the question; the plan adopted in such circumstances was to starve them out. Opposite to this great cave is a lesser one with a low entrance. At the further end of this the author found a quantity of detached human bones, and, close by, a number of others imbedded in the solid limestone wall of the cavern.

Two years ago the rumour of the great interest felt in Europe in the antiquity of the human race reminded him of these cave-remains; and so vivid were his first impressions that he was able to go straight to the grotto, and with a hammer detached the few specimens from the rock which were exhibited.

If any ordinary native of Mangaia were asked about these relics of humanity, he would merely say, they were "taito, taito rava" ("old, very old"), and this would probably delude the European inquirer into the belief that they were of remote antiquity.

The tradition of the "wise men" in relation to the matter is, that the sacerdotal clan of Mautara, about the year 1718 A.D., surprised and destroyed Ruanae's cannibal tribe at Pukuotoi, a spot about a mile from the grotto. This event has been celebrated in song by the chief Potiki in his 'Lament for Vaiaa,' beginning thus:—

Solo .... The clan of Ruanae has perished,
As the reef covered with dead fish
Is the ground where they fought.

The entire victorious clan in chorus ... Let their carcases rot there!
Let their carcases rot there!

The bodies of some of the most distinguished were conveyed by their friends to the neighbouring caves and piled up there on wooden platforms. As the wood decayed, the bones were scattered over the damp floor.

The author procured some human bones of a more remote date, but in a much better state of preservation, a circumstance owing to the dryness of the cave in which they were found. These relics are stated by the "wise men" to be the remains of invaders from Tubuai, who effected a landing, and at first overran the island in the reign of Anne, but were eventually deceived and destroyed by the aborigines of Mangaia. Anne was the fourth sovereign chief of the little island; the battle which sealed the fate of the invaders was the fourth ever fought on Mangaia. At first sight the bones chipped out of the rock seem to be of much higher antiquity than the relics of the invaders from Tubuai; yet this is not the case.

The author concludes that the Hervey islands have been peopled in comparatively recent times; and so, too, of the Eastern Pacific islands. Tahiti and the neighbouring islands were all peopled some generations previous to the Hervey islands, the first island colonized in that neighbourhood being Raiatea, the centre of a widely extended and most sanguinary worship. Those islanders speak of their ancestors as having come *up* from the "po" = "darkness," or from "Hawaiî" = "Savaii." By "coming up out of darkness," no doubt the lands where the sun sets are intended; and "Hawaiî" is Savaiî, the largest island in the Samoan group. Of course "Hawaii" naturally reminds one of the great island in the Sandwich group; but the traditions of the Eastern islands all point westward, *not* northward.

A close study of the question for several years past induces the author to believe that the Hervey group was colonized about five or six centuries ago. The grounds of his belief are:—

1. The fact that when in 1823 Rarotonga was discovered the twenty-fourth "Makea"* was reigning. Allowing to each "Makea" a reign of twenty-five years, we have a total of 600 years. Another chief on Rarotonga, named "Tinomana," was in 1823 the nineteenth in direct descent from "Makea Karika," who came from Samoa. Allowing, as in the former instance, twenty-five years to each chief of this tribe, we obtain a total of 475 years.

2. The "wise men" of Atiu confessed to the writer that the ancestors of the present chiefs sprang from the regal Makea family of Rarotonga.

3. The well-known succession of priests of the three principal gods of Mangaia supplies us with nine very long lives. Allowing each priest to discharge his functions during the long (probably too long) period of fifty years, we get a result of only 450 years. The Mangaians themselves trace their origin to ANAIKI, or "netherworld." Now "Avaiki," "Hawaiî," and "Savaiî" are but slightly different forms of *one word*. In their songs and myths are many references to "the hosts of Ukupolu," undoubtedly the "Upolu" of Samoa. The other islands of that group are all mentioned in ancient Mangaian song.

But whence did the Samoans spring? Many words in their dialect are identical with that spoken on the south-eastern peninsula of New Guinea. Of the Asiatic

* "Makea" is a regal title, like "Pharaoh" and "Candace" of Scripture.

and Semitic origin of the Samoans and Eastern Pacific Islanders generally, the author has no doubt.

The instruments produced were not from the cave, but were actually used by the present or last generation. The author pointed to a remarkable oval sling-stone of stalagmite limestone, to the axes of jade, basalt, and greenstone, to the hafted axes of basalt, as illustrating by recent examples the history of the extinct stone age of Europe.

On the Passage of Eastern Civilization across the Pacific. *By* J. Park Harrison, *M.A.*

The fact that a drift-current from the west deposits wood and other light materials upon the shores of Easter Island, and then, turning northwards, joins the Chilean stream in its course towards the equator, goes far to support the traditions of the Eastern islanders, as well as the inhabitants of the coast of Quito, that strangers arrived amongst them many centuries ago from the west. The author mentioned that there is a tall race, with marked aquiline features, who formerly followed sun-worship and artificially elongated the lobes of the ears, that can be traced across the Pacific in two directions—one through the islands of Sancta Crux to California, the other through the Tonga Islands, Oparo, and Easter Island to Peru. Numerous distinctive analogues along both routes appear to connect the people alluded to with our east. Both in stature and profile they differed from the races with which they mingled, and became more or less amalgamated.

On a hitherto undescribed Neolithic Implement. *By* J. Sinclair Holden, *M.D., F.G.S., M.A.I.*

This implement is a flint saw, which seems peculiar to the primitive dwellers of the Glens of Antrim in the later stone period. It has been found in several dolmens by the Earl of Antrim and the writer. That it is rare and local is confirmed by its absence from the stone-implement collections in our museums, and its also not being mentioned by Mr. Stevens, Mr. Evans, and other writers on this subject. It is formed from a flat flint flake by chipping a curved portion out of its thin margin, the edge of which is bevelled and finely serrated. When held in the hand and semirotated, it would be an excellent tool for sawing notches in a round stick or bone, and may have been thus used to notch arrow-shafts in order to securely tie on the barbs, and would also serve for marking tallies.

Being found so purely local puts aside the suggestion of it having been used for any religious rite. It is much too delicate to have been employed as a scraper, and the manner in which old ones are worn and fractured negatives this opinion. Though very unlike every flint saw hitherto met with and described, this genuine implement seems to admit of no other designation.

A true Cerebral Theory necessary to Anthropology.* *By* J. Kaines, *D.Sc., M.A., Tr. L.A.S.*

Dr. Kaines began his paper by stating that anthropology, the science of mankind, cannot be more than instituted as a science while physiology, or the science of individual life, is incomplete. To render human and comparative physiology complete, cerebral physiology must acquire positivity.

Further, the aim of the author was to show that phrenology was the only *de facto* science of mind, it being based on physiology; while certain pseudo-sciences of mind, based on theological and metaphysical data, were unscientific. Dr. Kaines briefly reviewed the labours of Gall and others who had founded and established organology, and asked why it was that the science of cerebral physiology had fallen into apparent disrepute. He went on to show in what way the strength and weakness of the system were regarded by eminent thinkers and physiologists, such as

* The above paper is printed *in extenso* in 'Anthropologia,' No. II.

G. H. Lewes, Broussais, De Blainville, and A. Bain, nearly all of whom agreed that the fundamental position of phrenology was demonstrated. The author quoted freely from A. Comte's 'Philosophie Positive,' tome iii. "Biologie"—a philosophical exposition and criticism of Gall's doctrine, and the means whereby it might become, physiologically and anatomically, scientific. He said, "Phrenological analysis has, then, to be reconstituted, first in the anatomical, and then in the physiological order; and finally the two must be harmonized; and not till then can phrenological physiology be established upon its true scientific basis." "If our existing phrenology isolates the cerebral functions too much, it is yet more open to reproach for separating the brain from the whole of the nervous system." "Phrenology has too much neglected the great influence to which the chief intellectual and moral functions are subject from other physiological phenomena, as Cabanis pointed out so emphatically while preparing the way for the philosophical revolution which we owe to Gall."

The paper concluded by showing that anthropology could benefit nothing from old systems unscientifically based, and that anthropologists could only prosecute their studies successfully by discarding as idle all questions of origins of species, whether human or animal, and of first and final causes, these questions being beyond settlement by such knowledge and such powers as we have.

On an Age of Colossi.

By John S. Phené, *F.S.A., F.G.S., F.R.G.S., F.R.I.B.A.*

This paper commenced with a slight sketch of the theory of the ages of stone, bronze, and iron, as generally recognized by anthropologists, for the purpose of bringing forward a feature which, in the author's opinion, would at a future period considerably modify present ideas on this subject—the geographical feature, the effect of which, he thought, could be hardly understood till we were able to correlate more perfectly the antiquities of distant countries. He argued that, assuming a wave of emigration from a common centre to bear forward any distinct characteristic, whether of these recognized features or of colossi, or otherwise, such wave might, in prehistoric times, while portions of it terminated abruptly near its source, upon desirable spots being attained, travel indefinitely by other sections over an enormous area, even giving rise to secondary or subwaves of exodus. This, in result, might produce the strange features, discovered by subsequent travellers, of a civilized or historic age setting in, either from a succeeding wave or some other cause, which would reach to the settlements from which the sub-exodus proceeded, but not follow the offshoots; hence, in an age highly historic, and civilized in a given geographical area, there might be found people with the same features, traditions, myths, and roots of language in a barbarous or prehistoric age or condition outside that geographical area; and in consequence any particular age so identified might be, or seem to be, indefinitely long from the retainers of its characteristics wandering beyond the reach of communication. That such waves had passed over distant lands, he argued by illustration and analogy, through various architectural features, special and peculiar, found in remote and distant countries. After drawing attention to the inhabitants of what he termed the three great centres of colossi, and which he designated as Egyptian, Malayan, and pre-Mayan, or Mexican, he illustrated by diagrams and drawings the favourite emblems of those creators of colossi, from which it appeared that on a broad basis there was both an architectural and emblematic similarity in their works, the pyramid, the monolith, the obelisk, and the elevated platform being prominent features in each; the worship of the sun apparently common, and colossal emblems of the human figure, reptilia, and birds abounding. Easter Island, as representing Polynesia, was included, and the physical features and climatic conditions were found approximating in these different centres. He expressed a belief that a careful study of the poetic language of the Singhalese would aid and stimulate researches in the forest-covered cities of Ceylon, and those of the ancient Maya (if possible) and of the Quiché peoples would unravel the mystery of the now impenetrable cities of Mexico and Central America. While these cities, with their colossi,

were so buried, we had much to learn of the history of the human family, and the age in which their colossi were executed.

This part of the question was (he considered) too extensive for a single paper, and he would confine himself, by way of illustrating his argument, to what seemed to him the result of an offshoot from such a preceding wave as he had supposed, which he considered had laved its final billow on the shores of Britain. He first pointed out that the highly civilized nations of Greece and Rome were not originators of colossi, but elaborators of the raw material ideas (if he might so express himself) of the Egyptians and other earlier nations, as shown by their exquisite symmetry, and the costliness of the materials (gold and ivory) of which some of their most gigantic colossi were constructed, as quoted by Pliny, Pausanius, Strabo, and other ancient writers. He then gave a number of examples of similar accompanying features in Britain, Egypt, Mexico, and Malaya. He found parallels of design in the plans of some Oriental cities (as Rhodes), in those of some of the Chinese and Sardinian tombs, and the horseshoe device of Stonehenge, all of which assimilate; in the circle of Copan and those of Avebury, the Giant's Ring near Belfast, and others; and finally argued that we had not only these collateral evidences, but actual colossi of the ancients in these lands, in enormous monoliths, in venerated idols—as, amongst others, the celebrated rock, the traditional goddess Andras, and the enormous Wilmington giant, both in Sussex; and the latter, as the result of his attracting attention to it, is now being restored, with the consent and kind assistance of the Duke of Devonshire. This figure, he quoted Cæsar and Strabo to show, agreed identically with the description given by those writers of the vast Celtic deity, to which were sacrificed human victims, wild beasts and cattle, and of which Cæsar says "they had many images."

Notes on Stone Implements from British Guiana. By F. W. Rudler, *F.G.S.*

The specimens exhibited to the department and described in this communication were collected by Mr. C. B. Brown during his recent survey of British Guiana. One of the implements, formed apparently of diorite, presented the form of an acute cone, 6 inches high, with a flat circular face, about 2 inches in diameter: this face seemed to be well adapted for grinding or pounding. Mr. Franks had pointed out the similarity between this implement and others from the north-west coast of America, where they are used as hammers. This specimen was found on the Burro-burro river. Among the other implements was an adze in diorite, found on the site of an ancient Indian village at Skeldon, at the mouth of the Corentyne river. It was accompanied by a small carved image in a green steatitic mineral, by fragments of coarse pottery, and by a large number of bones, including those of the tapir.

On the Relation of Morality to Religion in the Early Stages of Civilization. By Edward B. Tylor, *F.R.S.*

Investigations of the culture of the lower races of mankind show morality and religion subsisting under conditions differing remarkably from those of the higher barbaric and civilized nations. Among the rudest tribes a well-marked standard of morality exists, regulating the relations of family and tribal life. There also exists among these tribes some more or less definite religion, always consisting of some animistic doctrine of souls and other spiritual beings, and usually taking in some rudimentary form of worship. But, unlike the higher nations, the lowest races in no way unite their ethics and their theology. As examples, the Australians and Basutos of South Africa were adduced. The Australians believe spiritual beings to swarm throughout the universe: the Basutos are manes-worshippers, considering the spirits of deceased ancestors to influence all the events of human life; wherefore they sacrifice to the spirits of near relatives, that they may use their influence with the older and more powerful spirits higher in the line of ancestry. Yet these races and many others have not reached the theological stage at which man's good or evil moral actions are held to please or displease his divinities, and to be rewarded or punished accordingly. The object of the present paper is to

trace the precise steps through which the important change was made which converted the earlier unethical systems of religion into ethical ones. This change appears to have been a gradual coalescence between the originally independent schemes of morality and religion.

In order to show the nature of such coalescence between religion and other branches of culture not originally or not permanently connected with it, the author traced out, on an ethnological line, the relations between religion and, on the one hand, the rite of marriage, on the other hand the profession of medicine.

First, as to marriage. The evidence of the lower races tends to show that at early stages of civilization marriage was a purely civil contract. Its earliest forms are shown amongst savage tribes in Brazil and elsewhere. The peaceable form appears well in the custom of the marriageable youth leaving a present of fruit, game, &c. at the door of the girl's parents; this is a clear symbolic promise that he will maintain her as a wife. Another plan common in Brazil is for the expectant bridegroom to serve for a time in the family of the bride, till he is considered to have earned her.

The custom of buying the wife comes in at a later period of civilization, when property suited for trade exists. The hostile form of marriage, that by capture, has also existed among low tribes in Brazil up to modern times, the man simply carrying off by force a damsel of a distant tribe—the antiquity of this "Sabine marriage" in the general history of mankind being shown by its survival in countries such as Ireland and Wales, where within modern times the ceremony of capturing the bride in a mock fight was kept up.

Now in none of these primitive forms of marriage, as retained in savage culture, did any religious rite or idea whatever enter. It is not till we reach the high savage and barbaric conditions that the coalescence between marriage and religion takes place, as where among the Mongols the priest presides at the marriage feast, consecrates the bridal tent with incense, and places the couple kneeling with their faces to the east, to adore the sun, fire, and earth; or, as where among the Aztecs, the priest ties together the garments of the bridegroom and bride in sign of union, and the wedded pair pass the time of the marriage festival in religious ceremonies and austerities. So complete in later stages of culture did this coalescence become, that many have come to consider a marriage hardly valid unless celebrated as a religious rite and by a priest.

Second, as to the relation of the profession of medicine to religion. In early animistic philosophy, one principal function of spiritual beings was to account for the phenomena of disease. As normal life was accounted for by the presence of a soul operating through the body in which it located itself, so abnormal life, including the phenomena of disease, was accounted for in savage and barbaric culture as caused by some intruding spirit. Thus the belief in spiritual obsession and possession becomes the recognized theory of disease, and the professional exorciser is the doctor curing disease by religious acts intended to expel or propitiate the demon. Since the middle period of culture, however, this early coalescence has been gradually breaking away, till now in the most civilized nations the craft of healing has become the function of the scientific surgeon or physician, and the belief and ceremonies of the exorcist survive in form rather than in reality.

By these cases it is evident that coalescence between religion and other matters not necessarily connected with it may take place at different periods of culture, and also that this coalescence may terminate after many ages of adhesion. Having shown this, the author proceeded to ascertain exactly when and how in the history of civilization the coalescence of morality and religion took place.

First, where manes-worship is the main principle of a religion, as among some North-American tribes and the Kafirs of South Africa, the keeping up of family relations strongly affects the morality. It is, for instance, a practice among the rude races to disinter the remains of the dead or to visit the burial-place, in order to keep the deceased kinsman informed as to what takes place in his family, in which he is often held to take the liveliest interest. Thus it is evident any moral act of an individual damaging to his family would be offensive to the ancestral manes, whose influence must therefore strengthen kindly relations among the living members of the tribe. Higher in the social scale this ethical influence of manes-worship takes

more definite form, as when in China the divine ancestors of an emperor will reproach him for selfish neglect or cruelty to his nation, and even threaten to induce their own highest divine ancestor to punish him for misdeeds. Thus among the ancient Romans the Lares were powerful deities enforcing the moral conduct of the family, and punishing household crime.

Second, the doctrine of the Future Life begins at the higher levels of savagery to affect morals. In its first stage the doctrine of metempsychosis is seen devoid of moral meaning, men being re-born as men or animals; but when the distinction appears in the higher savagery between migration into vile or noble animals, it is not long before this distinction takes the form of reward or punishment of the good and wicked by their high or low re-incarnation, an idea which is the basis of the Buddhist scheme of retributive moral transmigration through successive bodies. In its earlier stages this doctrine was one of mere continuance, as where South-American tribes expected the spirits of the dead to pass to another region where they would live as on earth. Here the distinctions of earthly rank are carried on, the chief's soul remaining a chief, and the plebeian's soul a plebeian, but no sign of moral retribution appears. The first stage of this seems to be where warriors slain in battle are admitted to the paradise of chiefs in the land of the Great Spirit. This idea, which comes into view in several districts, leads to the fuller moral scheme in which goodness of any kind, valour, skill, &c. are more and more held to determine the difference between the next life of the good man in happy hunting-grounds, or of the bad man in some dismal wilderness or subterranean Hades. In the higher nations this element becomes more and more distinctly marked, till the expectation of future reward and the fear of future punishment becomes one of the great motives of human life.

Third, when theology among the rudest tribes is mostly confined to consideration of ghosts, demons, and nature-spirits, the intercourse with these leads to little inculcation of moral action. It is when ideas of the great deities become predominant, when men's minds are turned to the beneficent action of the Sun, or Heaven, or Earth, or to a Supreme Deity yet above these, that it is conceived that the order of nature includes moral order of human conduct. Then, as in the religion of ancient China, the universe and its Supreme Deity are regarded as furnishing the model and authority regulating man's actions towards his kindred and his subjects. Thus there presents itself, not at the beginning but the middle of the development of religious ideas among mankind, the leading principle of a moral government of the world and its inhabitants.

In these three ways it appears, from the evidence of ethnology, that the vast transition was made from the earlier unethical to the later ethical systems of religion.

GEOGRAPHY.

Address by Sir RUTHERFORD ALCOCK, *K.C.B., President of the Section.*

I CANNOT help feeling that my claim to the title of a Geographer is much too slight to warrant my appearance here as President of the Geographical Section of the British Association. My misgiving as to the fitness of the choice would, indeed, have precluded my accepting the honour, had I not believed that the main object of this Association is to receive and give ventilation to any new ideas or scientific contributions, to secure the attention of a larger audience of scientific men than could otherwise be easily obtained for any special subject, and to promote the free interchange of opinions between persons of various pursuits and qualifications. For this end it is not necessary that the President should himself be competent to take a leading part in discussing the many interesting and scientific subjects which are likely to be brought forward. It is enough, I conceive, that he should appreciate at their just value the studies of those who are willing to com-

municate the results of their labours, and be ready to promote the candid and impartial consideration of any papers to be read and discussed. With this assurance I will throw myself upon your indulgence for any shortcomings, and proceed with the business before us.

The admirable review of geographical progress during the past year presented to the Geographical Society at its last Anniversary in May by Sir Henry Rawlinson, must be too fresh in the memory of those of my hearers who are interested in geographical pursuits, to require any attempt on my part to go over the same ground. It has been published in the volume of the Society's Transactions for the year, and it would be superfluous, if not presumptuous, on my part, therefore, to occupy your time by any repetition on the present occasion.

If I venture at all upon this field of geographical achievements it will be rather with a view to draw your attention to the wide scope and application of Geography as a science, and to the mode in which geographical explorations and discoveries lead to important results in various directions. Geography, in a popular sense, is apt to be too much associated with a mere description of the configuration of the earth, with its seas and continents, illustrated by maps. But before Geography could fulfil even this very narrow and restricted conception of its proper functions—before, indeed, it could exist in any but the rudest and most imperfect shape, such as we see in mediæval maps—great progress had to be made in astronomy and mathematics. Without these two sister sciences, Cartography, or the process of depicting relative distances and places on the earth, either on maps or globes, could not be carried out with any approach to certainty or accuracy. Explorations with a compass, and measure of distance estimated by the number of days' journey, gave little more than such results as we find recorded in Ptolemy's works. The map of the world preserved in Hereford Cathedral is a curious sample. There the history of our race, as well as the distribution of countries, are given on purely theologic and historical or legendary data. Beginning at the top of the circle with Paradise, it presents nearly every thing in nature and fiction, but Geography, to the gaze of the curious. Until the discovery of the gnomon, and the means of fixing the latitude and longitude of any place by observations of the celestial bodies had been perfected, Geography could have no existence as a science. It owes much, also, to its intimate connexion with various branches of knowledge, and investigations into the nature and mutual relations of objects on the earth, or forming a part of its crust, which seemingly had, at the time of their prosecution, no direct bearing on Geography or its objects. In modern times only it has been fully recognized that Descriptive Geography is of little value apart from Physical Geography; and these, again, lose much of their interest without their relation to Political and Historical events are traced.

Astronomy had, in effect, to supply the means of reducing to a systematic and available form the accumulated materials which must now constitute Geography, by first enabling geographers to determine with accuracy the relative position of places, with their distance from each other, and their exact latitude and longitude. But this power once gained, the importance of Geography and its influence over the material interests of mankind soon became apparent, and its progress as a science has gone on increasing at a proportionately rapid rate. It was in vain that Marco Polo twice traversed Asia in its whole breadth, from the Mediterranean to the Great Wall of China, and lived to return and recount all the wonders he had seen to his countrymen within the prison walls of Genoa. It only earned for him the derisive *sobriquet* of Marco Millione, from the supposed fabulous nature of the statements he made; and although he contributed so vast an amount of new facts to the knowledge of the earth's surface, it does not appear, even when his book was printed a century and a half later, that it had any material effect upon the science of Geography, for want of the higher knowledge required to systematize and assimilate the whole.

Later (as Colonel Yule has well pointed out in his admirable edition of Marco Polo's book), when Vasco de Gama, doubling the Cape of Good Hope, reached the Malabar coast, and "the great burst of discovery eastward and westward took place," the results of all attempts to combine the new knowledge with the old were most unhappy. The first and crudest forms of such combination attempted

to realize the erroneous ideas of Columbus regarding the identity of his discoveries with the regions of the Great Khan's dominion. It was, in consequence, some time before America could vindicate its independent position on the surface of the globe; while Jerusalem long remained the central point of the map, because it was so described in the book of Ezekiel. Down nearly to the middle of the 15th century the map of the world was, in its outline, as it had been handed down by Biblic and other traditions sanctioned by some Fathers of the Church, "sprinkled with a combination of classical and mediæval legends."

How important geographical science has become since that date, and how each day brings fresh materials and illustrations of the importance, I need hardly point out. The discovery by the Portuguese of a sea-route to India entirely changed the whole course of commerce between Europe and Asia. A trade which had first enriched Tyre and the Phœnicians, and in Solomon's reign tempted the Jews to build fleets on the Red Sea—which, still increasing, made Alexandria the great emporium of Indian wares, while in more modern times it helped to create a city of merchant princes in Venice,—abandoned from that date the caravan routes of Asia. The Adriatic ceased to bear rich argosies from the East, and Nuremberg, with other free cities of Germany, equally lost a source of wealth in distributing Eastern merchandise.

This was the first and most pregnant of the great changes caused by the geographical discoveries of the 15th century. The planting of the European race in North and South America, and especially of our own stock in the North, was a second result, which promises to make English the predominating language of the world, and to spread British institutions and love of liberty over the four quarters of the globe. How it has affected the destiny of the Aborigines over the new world laid open by geographical discoveries is a less satisfactory subject of reflection; but whatever the estimate may be of relative good and evil following in the wake of such explorations, the influence exercised on the destinies of nations cannot be questioned; and amidst all the workers who contributed to these results, great and lasting as they have been, Geographers may rightly claim a foremost place.

Few things in the retrospect of past intercourse and knowledge of each other among nations widely separated are more remarkable than the continuous communication across the whole breadth of Asia between east and west, which seems always to have been maintained for purposes of traffic, from the earliest periods. No dangers of the way, no physical obstacles of mountain-ranges and great rivers or deserts, no length of time nor ignorance of the geographical bearings of any portion of this area of so many thousand miles, seemed to have acted as deterrents. Even the softly nurtured Venetian merchants were undismayed; and Marco Polo's book of his father's travels and his own abundantly proves that time must have borne a very different value in those days to that which prevails in this century. In the first journey to China we find they stayed one year at Sarai, on the Volga, and another at Bokhara. It is true they found it difficult to get either backward or forward, owing to the unsettled state of the country; but this did not in any way militate against their accepting an invitation, under a safe escort from the Envoys of Alan, the "Lord of the Levant," to proceed to the court of Kublár Khan, in China—a journey which occupied them a whole year. Whether the profits of any successful venture were so enormous as to afford adequate return for the time, or the merchants of those days were so fond of adventure and exploration that they were content with less profit than modern commerce expects, I am not prepared to say. But whatever may be the true explanation of this apparent diversity, we may congratulate ourselves that each year many geographical explorations, accompanied as these now are by careful and scientific observations, and the immediate registering of new facts in accurate collation with all previously acquired data, sensibly diminish the extent of unknown territory, and by so much not only facilitate the development of a constantly increasing commerce, but largely contribute to the diminution of causes of national contention, in the application of treaties and the determination of boundaries.

We have had several very striking examples of this within the past year; and although this is not the place to enter into the merits of the disputed questions as to limits in any of the cases, I may be permitted to refer to them in general

terms as illustrations of the important service which geographical science is enabled to render to Nations and to States in the higher field of political combinations and diplomatic negotiations. It has been well said that the surveyor is likely to do more in future than soldiers to prevent war; and the more frequently the scientific geographer precedes negotiations, the less ground there will be for doubt or disputes about boundaries—a most fertile subject of quarrel in all ages. Is it not quite certain, for instance, that if accurate and complete surveys had been made of the Straits between Vancouver's Island and the American coast, and appended to the treaty of 1846, which was intended to settle the Oregon boundary, with a line drawn exactly where it was intended the delimitation should take place by the two negotiators, no dispute could have arisen? It may have seemed enough to define the north-west water boundary to be "a line drawn from the middle of the channel which separates the Continent from Vancouver's Island southerly through the middle of the said Channel and of the Fuca Strait to the ocean,"—more especially, perhaps, as the existence of the De Haro and Rosario channels, about which the dispute has arisen, was known to the negotiators. Yet how long and fierce the contention has been between two great powers! and though now peacefully decided, we all know that it has for more than 25 years been one of those questions which might at any time have been a cause of war between two kindred nations,—the greatest calamity that could well befall either the one or the other.

The result of Sir Frederick Goldsmid's geographical labours in the east of Persia during the past year has added another example of the inestimable political value of accurate geographical surveys. In Asia more than any other country perhaps is this necessity felt. Papers have been read at the Geographical Society describing the journey of the Arbitration Commission from Bunder Abbas, through Kerman to Seistan, and reporting fully on the districts which have been so long in dispute between the Persian and Afghan governments. The line of delimitation between the two countries has been decided by the labours of the Commission, and the last mail from India announces its acceptance by both parties. My chief object in referring to it is to show the great and important services which not only may be, but are actually rendered by geographical labours under able direction, and how much is to be gained, both in the interests of peace and of science, from the adoption of a practice of avoiding political complications by determining disputed lines of frontier through the agency of mixed commissions and professional engineers. That it should be generally adopted in the East must be the earnest desire alike of geographers and statesmen, and converts to the principle are rapidly increasing. The latest news from Constantinople brings the gratifying intelligence that the Sultan of Turkey and the Shah of Persia have mutually agreed to refer their contentions about the boundaries between the two States to a mixed Commission of this kind. The delimitation fixed by the British Government on the Upper Oxus by similar action is a pledge of peace with Russia. These are so many triumphs of an enlightened policy, by which disputed boundaries are settled, not by the sword, but by geographical observation, the accuracy of which cannot be contested. In this case it was rendered difficult, and all the more important politically, because, as Colonel Yule has recently demonstrated, the whole geography of the region of the Upper Oxus and surrounding country had been falsified by Klaproth. In all the pseudo-travels that he invented he had imposed alike upon the British and the Russian Governments; and the consequences of such falsification might have been most fatal, for it vitiated the maps of the Russian Government, and with it their diplomacy. Fortunately our own information of the geography of the trans-Himalayan regions had so much improved since Klaproth exercised his ingenuity, that it became possible not only to show where the falsification existed, but how one great source of error had arisen. Colonel Yule has proved, in a paper now published in the 'Transactions of the Geographical Society,' how, by a certain square of the Chinese Map constructed in 1759 (which was the groundwork of Klaproth's geographical knowledge) having been accidentally turned round through an angle of 90°, the mistake originated by which the district of Wakhân for instance, instead of being laid down in the same parallel as Badakhshan, was placed in the map 100 miles to the northward, and thus appeared to Prince Gortchakoff to be conterminous with *Kara-tegin*.

There is no nation, perhaps, which has so much reason to value geographical science and the art of map-making at a high rate as the Russians. In their rapid advance across the steppes and mountain-ranges of Northern Asia southward into the valley of the Amoor and Manchuria on the east, and to Khiva and Samarcand in the west, they have taken many courses; but in all they have had the immense advantage of not only knowing the territories they coveted, but being able to place them accurately on maps. The late Mr. Atkinson, a great traveller in Siberia and Central Asia, gives more than one graphic and, there is every reason to believe, perfectly veracious account of how negotiations for territory with Asiatics may be successfully and even peacefully conducted, at a very small cost when thus aided and prepared. First an exploring party starts for some unknown region, ostensibly, it may be, for hunting, well armed and prepared to note accurately the physical features of any country they may traverse. The first exploration accomplished, a second follows, better provided for an actual survey and geological and mineralogical researches. These being completed, negotiations are opened with the chief of the tribe to whom the territory in question belongs. One of these transactions in 1848 ended in a considerable district in the Kirghis Steppe, lying between the Targ Abatai and the Irtisch, already ascertained to possess valuable silver- and lead-mines, being transferred from the Sultan and chiefs of the Great Horde of Kirghis to the Emperor of Russia (or, as he is better known to the Kirghis, the "Great White Khan") for a sum of 250 roubles, a gold medal, a sword of honour, and half a dozen handsome khalats or robes for the Sultan, Mulla, and the five or six head chiefs.

In these mysterious and hitherto inaccessible regions of Inner or Central Asia, geographical knowledge is almost a necessary qualification in any Power which seeks further intercourse and access. To Russia, of course, it is matter of primary importance, situated as she is in direct contact along all her southern border with the nomade races which occupy the vast regions stretching across the continent between her and all the southern ports and seas; but scarcely more so, perhaps, than to Great Britain, as another great Asiatic Power,—the only one of equal pretensions, strength, and influence in the East by its command of Western resources and Asiatic territory. A knowledge of the geography of the regions lying between the Caspian and the Amoor is, indeed, power of the most valuable kind. When the Russians secured possession of the upper portion of the Zarafshan valley about Saware, they commanded the waters on which Bokhara depends for its fertility and existence, and of course obtained a means of easy conquest. Thus, whether for conquest or for commerce, Geography is the best ally and a necessary pioneer. If we look again at the map, showing the complex systems of mountains separating the plains of India from Eastern Turkestan and the upper tablelands and valleys of Central Asia, we shall find that they are not simple ranges, like the Alps or the Pyrenees, which can be crossed by a single pass, as Mr. Shaw has so well shown, but are composed of many chains, enclosing considerable countries within their valleys. Thibet and Cashmere are examples of this. Eleven passes, we are told, have to be crossed in travelling from India to Turkestan; and of these, only two are lower than the summit of Mont Blanc. Yet, thanks to the labours of many geographic explorers, impassable as these mountain-barriers seem, we know now that they are penetrated in such a manner by rivers, and so accessible by comparatively easy routes, that they form no insurmountable obstacle to peaceful commerce, although capable of a complete defence against force. Take, again, that range of the Thian Shan to the north and the Himalayan system to the south, which converge together as they run westward, and unite in a vast boss supporting the high plateau of Pamir, which the natives call the Bam-i-dunya, or "Upper floor of the World." Numerous valleys penetrate into it from east and from west, peculiarity which makes it far easier to traverse from east to west than from north to south—a fact which you will see at once has a most important bearing on the trade-routes.

The latest advance in this direction of Russia is fixed at present at Kulja, where she has established an important trading centre. This has been obviously dictated by a knowledge of geographical features giving her access to Eastern Turkestan; for although Kulja appears to be separated by difficult snowy mountains, yet these

are found to die away to the east; and from that point Mr. Shaw tells us Russia has it in her power to push her advance or her trade in two directions over level country, either eastward to China, or westward to Turkestan.

Geography, it is clear, therefore, in these regions, is the right hand of Rulers and of Generals, and determines alike the march of armies and the advance of merchants. Nothing can be done by either without its aid. It is impossible, however, not to admire the energy and indomitable spirit with which Russia, claiming and freely using all the assistance scientific geography can give, utilizes the knowledge thus secured. Mr. Shaw relates how the Muzat Pass, leading between Aksu and Kulja, lies over a formidable glacier; and he was assured that forty men were kept at work in the summer roughing the ice for the passage of the caravans. With such a rival it must be evident, if we are to compete in the same field with any success, that both Government and merchants must put forth all their strength, and neither be scared by physical obstacles nor daunted by expense and risks. This seems to me the great lesson which all these accumulated facts convey. Geography has shown the way, it is for merchants to follow, and Government, if need be, to aid in removing obstacles not otherwise to be overcome.

The connexion between history and geography, and the important bearing of each upon the other, was scarcely recognized until the second half of the last century, when several historical travellers gave, with their researches into the ancient history of Greece and Western Asia, many details of physical geography, and showed how essential a knowledge of these were to any perfect understanding of the events taking place in the several localities. They must be studied together, as the nature of the ground on which a battle has been fought, or a campaign conducted, must be studied, to understand the movements of the contending forces and the design of the leaders.

The late Dr. Arnold, in his lectures on history, insisted much upon the mutual relations of history and geography, and the important light which a study of physical geography throws upon the national conditions of life, social and political. "The whole character of a nation," he observes, "may be influenced by its geology and physical geography. Again, geography holds out one hand to geology and physiology, while she holds out the other to history. Both geology and physiology are closely connected with history. The geological fact of England's superior richness in coal over every other country lay at the bottom of the corn-law question. The physiological fact that the tea-plant was uncultivated in any other climate or country than China gave a peculiar interest to our relations with it." And it would be easy to give many examples of this intimate connexion between geography and history, and the mutual aid they afford.

We have seen how possession of the head sources of the water supplies could determine the fate of a country like Bokhara. And the distribution of river-courses mainly determines the location of great populations, and the development of trade and civilization by facilities of traffic and intercourse. Dr. Arnold, in the lectures already quoted, gives an admirable illustration in dealing with the map of Italy, which I cannot resist bringing under your notice.

The mere plan-geography of Italy shows a semicircle of mountains round the northern boundary, and another long line stretching down the middle of the Apennines. But let us look a little further, and give life and meaning to these features, as Arnold delighted to do.

"Observe, in the first place, how the Apennine line, beginning from the southern extremity of the Alps, runs across Italy to the very edge of the Adriatic, and thus separates naturally the Italy proper of the Romans from Cisalpine Gaul. Observe again how the Alps, after running north and south, where they divide Italy from France, turn then away to the eastward, running almost parallel to the Apennines, till they too touch the head of the Adriatic on the confines of Istria. Thus, between these two lines of mountains there is enclosed one great basin or plain, enclosed on three sides by mountains, opening to the east to the sea. One great river flows through it in its whole extent, and this is fed by streams almost unnumbered descending towards it on either side, from the Alps on the one side and from the Apennines on the other. Who can wonder that this large and rich and well-watered place should be filled with flourishing cities, or that it should have

been contended for so often by more poor invaders? Then, descending into Italy proper, we find the complexity of its geography quite in accordance with its manifold political divisions. It is not one central ridge of mountains, leaving a broad belt of level country on either side between it and the sea; nor yet is it a clear rising immediately from the sea on one side, like the Andes in South America, leaving room therefore on the other side for wide plains of tableland, and for rivers with a sufficient length of course to become at last great and navigable. It is a backbone thickly set with spines of unequal length, interlacing with each other in a maze almost inextricable. Speaking generally, then, Italy is made up of an infinite multitude of valleys pent in between high and steep hills, each forming a country to itself, and cut off by natural barriers from the others. Its several parts are isolated by nature, and no art of man can thoroughly unite them. Even the various provinces of the same kingdom are strangers to each other. The Abruzzi are like an unknown world to the inhabitant of Naples." This is what Dr. Arnold meant by a "real and lively knowledge of geography," which brings the whole character of a country before our eyes, and enables us to understand its influence upon the social and political condition of its inhabitants.

But such is the rapid progress of science and man's triumphs over nature, that the tunnel through Mont Cenis, or Fell's railroad over it, and the railroad which now pierces the Apennines and unites the eastern and western coasts of Italy, aided by telegraphic wires, already falsify Arnold's conclusion that no art of man can thoroughly unite regions so separated. And the influence these achievements must have over the unification of Italy, and the progress of civilization throughout the peninsula, can hardly be exaggerated.

Persia at the present day offers another striking illustration of the influence of physical causes on the progress of civilization and the destiny of nations. Apart from the consequences of ages of misrule, its physical geography has exercised a very adverse influence upon the country. Persia suffers from a great deficiency of rainfall; and although an immense supply of water comes from the mountains by the rains and the melting of the snow, it is lost in the plains and wasted, if not before, at least as soon as it reaches the great salt desert about twenty miles from Teheran. With the prevailing insufficiency of the rainfall on the plains themselves the whole country is becoming sterile; but if the abundant supply from the mountains could be intercepted before it reached the lower ground and collected into reservoirs, it might then be distributed by irrigation over the whole face of the land and play the same part as the Zarafshan or "Gold-scatterer" (so called for its fertilizing powers) in the rich cultivation of Bokhara. Perhaps this may not prove beyond the power of Baron Reuter to accomplish, aided by all the science and some of the capital of Europe. What further changes he may be enabled to effect by the introduction of railroads and telegraphic lines for facilitating trade and rapid communication, we may soon be in a position to speak from actual experience; for it is stated in the public prints that the proposed railway between Teheran and Resht is to be commenced at once, and that the plant has already left England. More extended operations are, it is understood, contemplated to the south of Teheran to Ispahan, and from thence to the Persian Gulf—perhaps also to the Turkish frontier. The former will open a direct line to India, and the latter to the Mediterranean, should the Turkish Government be willing to work in concert. Who can calculate the revolution in the whole aspect of the country and its life-sustaining powers, if a whole series of such measures should be carried through at once?

The part which Russia plays in the history of Europe and Asia, and the future which may yet be reserved for that Empire, is more a matter of physical geography than of politics or of policy, if we look to determining causes. What could Russia do, frozen in between two seas and with closed ports for more than six months in each year, but, guided by an infallible instinct (often exemplified in nations as in individuals), stretch out feelers towards the open waters and more genial climates? We have heard much of Russia's destiny driving her southwards to the Bosphorus, and eastward in the same parallel over the rich valleys of Central and Tropic Asia; but is it not a geographical necessity, far more than a political ambition, which has thus far driven her across the whole breadth of Asia until she

gained the Chinese ports on the Pacific, and southwards towards the mouths of the Danube, the sunny ports of the Mediterranean, and the head of the Persian Gulf? Until unfrozen rivers and ports could be reached, how could her people make any progress or develop their resources? It not only was a natural tendency,—as natural as the descent of the glacier to the valleys, forging downwards by a slow but irresistible pressure, but as inevitable. Obstacles may retard the progress, but not arrest it; and Russia is but following the course of nature as well as history in pouring down nomade hordes and hardy Scythians on the cultivated territories lying in a more genial climate. Railroads and telegraphic wires supply her with means of transport and quick transit over vast spaces never enjoyed by her great predecessors in this line of march. Let us hope, too, that more civilizing influences will follow her track, through regions never highly favoured in this respect, than marked the passage of a Genghis Khan or a Timor. 'The Times' observed recently that it was one of the happiest coincidences in history that, just at the time when the natural course of commercial and political development brings Central Asia into importance, there should still exist in the eastern border of Europe an empire retaining sufficiently the character of a military absolutism to render it especially adapted for the conquest and control of these semibarbarous communities. I am not altogether prepared to accept this high estimate of Russian ability and peculiar fitness for its self-imposed task, without qualification. That Russia, Asiatic in origin and type, autocratic, and armed with all the power which military science and discipline give, has some special fitness for the mission it seems to accept as a destiny, I am not inclined to deny. But whatever may be the decision arrived at on this head, it seems quite certain that as her progress in arms gives her control over Central Asia, so will be the exclusion, by protective or prohibitive tariffs, of all commerce but her own. It is only necessary to follow on the map, and in the history of the successive advances southwards, the progress made and the trade-routes established or extended within the last twenty years, to be convinced that trade and exclusive rights of commerce are among the principal objects which dictate the present policy of the empire. And, whatever may be the designs of Russia in her advances on Central Asia, it must be clear by this time that it is with her, and not with the nominal rulers of the States her armies have overrun, that we must count in any steps we may take for the peaceful prosecution of commerce. Strange and unexpected as are the reverses of fortune which have befallen nations and empires in all ages, and great and complete as has been the fall of many, there are few more striking than the interchange of parts between the Muscovite and the Mongol dynasties. The time was, as Colonel Yule remarks, when in Asia and Eastern Europe scarcely a dog might bark without Mongol leave from the borders of Poland and the coast of Cilicia to the Amoor and the Yellow Sea. As late as the 13th century the Moguls ravaged Hungary and conquered Russia, which they held in subjection for many generations. Sarai on the Volga was the scene of Chaucer's half-told tale of Cambuscan, when

"At Sarra in the Londe of Tartarie
There dwelt a King that werriéd Russie."

The times have changed indeed since then, and the successors and descendants of those same Moguls and Tartars have another tale to tell now, at Khiva and Peking.

Before I pass from this part of my subject, I would draw your attention to the vast field which yet remains in Asia for geographical research and exploration. The intimate connexion between such labours and the development of our commerce in the trans-Himalayan countries must have been made abundantly evident; and I would fain hope there will never be any want of competent volunteers (who may rival Mr. Shaw and Mr. Ney Elias, both distinguished and adventurous pioneers taken from mercantile pursuits) to show the way for others. Notwithstanding all difficulties and opposing influences, physical and political, there appears to be a large field for our commerce, and one capable of almost infinite expansion, where enterprise, skill, and industry may fairly count upon a good return.

As regards costly efforts in opening roads, it may perhaps seem doubtful to the Indian as to the Imperial Government, how far either would be justified in any large outlay. Nothing, however, is more to be regretted than doubt or hesitation

for the markets once monopolized by the Russians, we may seek in vain to open them to general trade at any later period. It is difficult to calculate how much we should lose; for the distance from the Indus to Vernoje and Kopal, two of the most recent markets of Central Asia founded by the Russians, is about one third of that from these places to the great fair of the Volga. Commercially this is of great importance, as these towns will become the centres whence the Tartar merchants will send forth their agents to disperse the goods among all the Kirghis of the Steppes. From these points they will also go to the Mongolian tribes, on the north of the Gobi; and this region, Mr. Atkinson assures us, contains a vast population. He even anticipates that, should such a trade be established, the merchandise will find its way through the country of the Kalkas into Davuaria, and to the regions beyond the Selenga and the sources of the Amoor, where it may advantageously compete with goods brought up the latter river; nor will the Siberians fail to avail themselves of its advantages. Whenever there shall be fairs on the Indus or beyond the passes of the Himalayas on the borders of Sikkim or Thibet, the Kirghis will send into India vast numbers of good horses annually. Silver and gold, the same traveller says, is plentiful in their country, and their other resources will in all probability be rapidly developed. The best mode of opening such a trade with Central Asia beyond question will be by fairs, or great marts, similar to Kiachta on the frontier between China and Russia, Irkutzk and Urga, and more recently at Irbit by the Russians. On this point we have also Mr. Atkinson's very decided opinion. He says, speaking of such fairs, "This I deem preferable to the English plan of consigning goods to agents either in Yarkand, Kokhan, or Tarshkend. Once these fairs are established, the Tartar and other merchants will attend and purchase the necessary articles for the people among whom they vend their wares. These men are thoroughly acquainted with the tribes and know all their wants. They are industrious and energetic in their calling, travelling over thousands of miles. They know every part of the country, and where to find the tribes in all seasons of the year; and it is by them that Russia distributes her merchandise over Central Asia. Wherever trade can be carried on at a profit, experience has shown that all natural obstacles have been surmounted by these hardy sons of the Steppe. It is well to have such commercial agents and distributors as allies and customers, whereas any attempt to locate English agents in their midst would create jealousy and excite fears lest they should lose their legitimate profits. Far greater dangers are encountered by caravans which travel from Kulja into the interior provinces of China than they will meet with between Yarkand, Kashgar, and the Indus." All that is required is to bring the goods from the plains of India through the passes to the border: and steps to this end are being actively taken in more than one direction.

In 1850 Lord Dalhousie sanctioned the commencement of a road, which, leaving the plains in the neighbourhood of Kalka, 36 miles from Umballah, should ascend to Simla and thence towards Thibet, through the temperate valley of the Sutledge, to Shipki on the Thibetan border. In the next five years this Hindostan and Thibet road, which was to unite India with Central Asia, had made such progress, that 115 miles of six-feet road had been completed; and it was anticipated that by the following spring but 25 miles would remain of unfinished work between Simla and China, and 60 between Simla and the frontiers of China. I regret to state that later accounts show the work to have been stopped; and this seems to be matter for deep regret, both on account of the large unproductive expenditure incurred for a work stopped short of completion, and the urgent necessity there is for secure access to the trans-Himalayan regions, while there is yet room for competition with Russian trade and influence. One of the great questions of the hour is, how best and most expeditiously to open up practicable roads from the plains of India to Central Asia, on the west to Turkestan, and eastwards to the borders of Thibet, and perhaps by British Burmah across the Shan States to the western provinces of China. But access to the markets of Central Asia is by far the most urgent and important; for, as I will presently show, the southern route through Burmah, were all difficulties overcome (and they are neither few nor slight), promises little in comparison with a more direct outlet for the Assam teas, and an interchange of goods and produce with the populations of Thibet, Turkestan, and Central Asia generally. Across the Himalayan barrier it appears there is a choice

of more than one or two practicable passes; that through Sikkim to the vicinity of Thibet offers the fewest difficulties, and in every respect promises the most speedy results with a moderate outlay. Other routes to the west, leading to Badakshan, and one by Ladak to Turkestan (where we have already an energetic and enterprising British representative in Mr. Shaw), and through the valley and passes of the Chitral, are beset by many difficulties, physical and political, though not more than a powerful Government like India may surmount. It has been said that if the Russians had such a question to deal with, the solution would not be long delayed; and no doubt they have solved some more arduous problems in the present generation. The enterprise, vigour, and perseverance which mark all their proceedings where the extension of their commerce or their dominion and influence over Asia from Peking to Constantinople (and especially towards the Khanates of Central Asia) are concerned, may leave us far behind in the race, and render them formidable adversaries, notwithstanding their merchants are weighted with distances so vast, that the 700 miles from the Indus to the other side of the Himalayas sink into insignificance. But I am not inclined to join in any condemnation of our own Government, without taking into consideration the inherent difficulties of the task, because they have not moved hitherto more rapidly in this direction. As regards access by Sikkim there ought to be both decision and prompt action. It is a protected state, and a late despatch of the Lieut.-Governor of Bengal to the Secretary to the Government of India expresses a hope to be able to connect the frontier mart at Dewangiri, once a very active trade-mart for the Tibetans and other adjoining districts, with the plains of India by a good road this next cold season. He considers it possible "to have a much easier, pleasanter, and more profitable communication with High Asia by this way than further west;" and speaks very decidedly as to the uselessness of any right of passage or trade through Nepaul or Bhootan. There seems every hope, therefore, that within a few months something effective will be done to open a trade-route through Sikkim and make the passes practicable. All that seems to be required is a branch railroad from the other side of the Kooshteen, where the Eastern Bengal Railway touches the Ganges, on through fertile Rungpore to the foot of the hills, and a road through the pass to the border, where a fair could be established and a trading station maintained.

Any direct access beyond the Thibetan border can only, in the present condition of affairs, be obtained by diplomatic action at Peking. The Chinese Government have hitherto created all the obstacles; and there is the greater reason for pressing a less restrictive policy upon the Chinese, that at the head of the Assam valley the Mishmi country communicates with Batang, a dependency of the Szechuen Province of China; and access to this point through the border would be a much more effective mode of tapping the south-western provinces of China than any routes through Burmah to Yunnan. Now that the Emperor's minority is at an end, and the Regency with it, the time would seem favourable for a strong and decided effort at Peking to remove the obstruction created by the jealous and restrictive policy of the Chinese rulers. But while Chambers of Commerce and Merchants are urging Her Majesty's Government to incur both outlay of money and grave political responsibilities for the furtherance of trade and the opening of new markets for our manufactures, it is necessary that they should be prepared to do their own part, and push boldly forward with their goods as soon as access can be gained—because any doubt on this head must necessarily tend to paralyze the efforts of a Government by the fear of working in vain. One cause of hesitation about the continuance of the magnificent work commenced by Lord Dalhousie in 1850, by which a great road was to be made from the plains to Shipki on the borders of Thibet, may have been certain doubts expressed by merchants as to any trade taking that route.

But I must not detain you longer. I will only glance at the projects for opening a trade by railway between Burmah and South-western China. The one route, so long advocated by Captain Spry, would cross over from Rangoon to Kianghung on the Meikong; and another, recommended by Colonel Fytche when Chief Commissioner of British Burmah, would extend from Rangoon to Prome, with a view to opening a trade *viâ* Bhamo.

Many memorials have been sent during past years to the Home Government to urge the undertaking of the first of these for the benefit of trade; but I am not aware that, important as the merchants have deemed it, the matter has ever been pressed on the Government by any Member of Parliament in the House of Commons, and I doubt very much such a line proving remunerative. Yunnan, so far from being, as described by some of the memorialists, both populous and productive, has been reduced to a desert waste by the civil war and the destruction of the Mahomedans, and for long years to come there can be little hope of commercial activity. It can scarcely be expected, therefore, that either the Imperial or the Indian Government will undertake to make such a railroad themselves, or to guarantee the interest for others. As regards the Government of India, it has always held, I think, of late years that the Indian revenue could not justly be charged with the cost of an enterprise which, however successful, could only benefit English trade, and very indirectly, if at all, Burmah. If any guarantee is necessary, therefore, it seems clear it must come from the Imperial and not from the Indian Government. There is one other consideration: recent news show that the French in Cochin China have by no means given up the hope of drawing any trade to be developed with the south-west of China by a much more direct and river-route to a port in the Gulf which they have recently secured for their own benefit. Although the French have not usually proved formidable rivals in Eastern trade, it is possible that, with such advantage of geographical situation, water-carriage, and proximity, they might seriously check any development of trade in a less favoured course.

Before concluding I must give you some information as to the papers which are likely to occupy your attention during this session.

Dr. J. McCosh will read a paper on an overland communication between India and China, a subject which he is qualified to pronounce an opinion upon, having made it his study for upwards of thirty years. As long ago as 1836, whilst serving in Assam, he furnished the Government with an official report, in which he pointed out the facility of connecting India and China by a grand trunk road; and he read a paper on the same subject before the Royal Geographical Society in 1860. He advocates the Munnipore route.

Mr. Ney Elias contributes a paper "On Trade-Routes through Mongolia and Zungaria." He gained the Royal Medal of this year from the Royal Geographical Society for his adventurous journey in 1872, as a private traveller, over the countries described in his paper, and is well known as an accomplished traveller, taking observations for laying down his route with rare completeness. He states in his paper that the only trade-route now open between Central Asia and Western China is that through Mongolia.

Mr. J. Thomson will read a paper on the Yang-tsze as an artery of communication. Mr. Thomson has been long before the public as a successful traveller and accomplished photographer of the scenery of distant countries. Some years ago he visited the marvellous ruins of temples and cities in Cambodia, and published a magnificent work on the subject, illustrated by photographs. Since then he has visited China and Formosa, and is publishing, in parts, a work of a similar character to his former one on Cambodia.

I believe Mr. Thomson will bring a set of photographs for exhibition.

Baron Richthofen will read a paper "On the Distribution of Coal in China."

He will perhaps read a second paper on the general subject of his travels. He is one of the most accomplished of Chinese travellers, and has traversed probably the largest extent of country. His published Report to the Committee of the Shangai Chamber of Commerce on his Explorations in the Provinces of Chili, Shansi, Shensi, and Sz'chuen is full of the most interesting information regarding the physical geography, resources, and products of the interior of China. He is present at the Meeting, one of the distinguished foreign *savans* invited by the town and the Association.

Capt. J. E. Davis will read a paper on the results so far of the voyage of the 'Challenger.' Capt. Davis was a member of Ross's great expedition towards the South Pole, and by his position in the Hydrographical or Scientific branch of the Admiralty is well qualified to deal with such a subject. The public have been

informed from time to time of the results of the deep-sea soundings and dredgings of the 'Challenger,' but Capt. Davis will supply by far the completest information.

The Rev. W. Wyatt Gill will give us an account of "Three visits to New Guinea." Mr. Gill, after twenty-two years spent in missionary life in the South Pacific, spent a short time at the mission stations in Torres Straits, and visited the mainland of New Guinea.

Recent Arctic Explorations.—The Spitzbergen and the Smith Sound routes are the two great rival highways of exploration towards the arctic basin, and discovery has alternately pushed nearer the pole by the one and the other. Till recently the Spitzbergen route held the palm, for by it ships had reached to beyond the 81st parallel, whilst on the American side no ship had been able to force a passage higher than the 79th degree of latitude; but in 1872 the American expedition, led by Capt. Hall, who has perished in the cause, making its way northward by Smith Sound, attained the highest point yet reached by ships, the latitude of 82° 16′ N., or to within 420 miles of the North Pole. Two expeditions, one from Austria the other from Sweden, are also in progress on the Spitzbergen side. The Austrian, under the leadership of Weybrecht and Payer, has passed beyond the limits of the remotest traffic into the unknown seas to the north of Siberia, and it is probable that no news of this voyage may reach civilized Europe for many months. The Swedish voyage had for its object to move northward by sledges from the Parry group of islands in the north of Spitzbergen, but has failed completely in this often-tried scheme, and spent the past winter at Morrel Bay, on the coast of the chief island of Spitzbergen. Early in the spring of this year another fruitless attempt was made to go north over the hummocked ice. Desisting unwillingly from these useless efforts, the sledge party turned along the coast of the north-east land of Spitzbergen to its extreme eastern point, and thence ascending the high inland ice, made a difficult passage across to Hinloper Strait, from whence the winter-quarters of the ship were again reached.

With regard to British enterprise in the Arctic regions there is little to report. Since the termination of the long series of brilliant exploits in the Polar regions at the end of the search after Sir John Franklin, England seems to have abandoned the field to rival nations. A few private expeditions to the Spitzbergen seas, notably those of Mr. Leigh Smith, who has again visited those regions this summer, alone represent British activity in the Arctic seas. However, the Royal Geographical Society does not allow the matter to slumber. An endeavour was made last winter to induce the Government to send out another expedition; and at the present time a joint Committee of the Royal and the Royal Geographical Societies is at work formulating a plan of action with a view to representing to Government the urgency of despatching an expedition in 1874.

Africa.—Of Dr. Livingstone and Sir Samuel Baker no fresh news has been received beyond what has been before the public. Two expeditions are now on their way to Central Africa in search of Livingstone and to cooperate with him. The Congo Expedition at last date (April 3) had reached Bembe, 130 miles from the coast, in admirable order. The East Coast Expedition had reached Rehenneko, 120 miles, but with the loss of one of the party, Mr. Moffat, who died near Simbo. Their plan was to reach Tanganyika, and finish the exploration of that lake, until Livingstone was met with. I had hoped to have seen Sir Samuel Baker here, that we might hear from his own lips and in fuller detail what he has accomplished. I do not quite despair yet; but up to the present hour I have had no communication from him since his arrival at Cairo on his homeward journey.

On the true Position and Physical Characters of Mount Sinai.
By CHARLES T. BEKE, *Ph.D., F.R.G.S.*

The identification of Mount Sinai is still uncertain. Though the great mountain-mass within the peninsula between the Gulfs of Suez and Akaba is generally looked on as containing the "Mount of God," it has hitherto been found imprac-

ticable to fix on any one of its lofty peaks as being incontestably the true Mount Sinai. The Ordnance Survey of the peninsula recently completed, however ably performed, has failed to remove the doubts and difficulties attending the subject, which have thrown discredit on the truth of the Bible history; for, though the topography of the peninsula has thereby been definitively settled, the relative importance of the various localities and their bearing on the Scripture narrative continue just as uncertain as ever.

According to Dr. Beke, the cause of this uncertainty is obvious. The primary question ought not to be whether this peak or the other peak within the peninsula has the greater claim to be considered the true Mount Sinai, but whether they are any of them entitled to that distinction. In his work 'Origines Biblicæ,' published in 1834, he contended that Mount Sinai is nowhere within that peninsula; and in the present paper he adduces proofs that this mountain is in reality a volcano, now extinct, situate within the *Harra Radjla*, a region of igneous origin, situate on the western side of the Sciptural "Land of Midian," now the great Arabian desert, and at no great distance to the east of the head of the Gulf of Akaba, or Sea of Edom, which (and not the Gulf of Suez) he looks on as the Red Sea through which the Israelites passed on their exodus from the Land of Bondage—the Mitzraim of Scripture not being identical with the Egypt of the Ptolemies, but lying altogether towards the north-east of it, in proximity to the country of the Philistines.

At the time of the Exodus Mount Sinai was in a state of eruption, the smoke and flame from its crater being described by the sacred historian as "by day a pillar of a cloud, and by night a pillar of fire," just as the poet Pindar speaks of Mount Etna as pouring forth "by day a burning stream of smoke, but by night a ruddy eddying flame;" and the volcano was not extinct in the time of the prophet Elijah, six centuries later.

Dr. Beke traces the route of the Israelites from Rameses to Succoth, and thence to Etham, which he identifies with the Wady Yetoum or Ithem of the present day, a side valley of the Wady Arabah, at the head of the Gulf of Akaba. From Etham the Israelites turned, and (as Dr. Beke reads the Hebrew text of Exodus xiv. 21) they encamped "before the mouths of the caverns, between the castle and the sea, over against its north end," the Castle thus mentioned being now represented by the Castle of Akaba at the north end of the Gulf. And after the Israelites had passed through the sea, their further route is traced to Marah, Elim, and again to the sea-coast at the entrance to the Gulf of Akaba; whence they proceeded in the direction of Mount Sinai, being guided by the pillar of a cloud and the pillar of fire during this portion of their journey, as they had been in that between Succoth and Etham. For a detailed statement of his views Dr. Beke referred to his pamphlet, 'Mount Sinai a Volcano,' recently published. In conclusion he expressed his desire to visit the volcanic region to the east of the head of the Gulf of Akaba, where he places the true Mount Sinai, for the purpose of verifying and completing his identification of that "holy ground," and so putting an end, once and for ever, to the doubts and difficulties that have so long existed respecting this the most venerable spot on the face of the earth; and it not being in his power to perform so costly a journey at his own expense, he expressed his confident hope of support from those interested in the settlement of so momentous a question.

On the Physical Geography of the Deserts of Persia and Central Asia. *By* W. T. BLANFORD, *F.G.S., C.M.Z.S.*

The deserts of Persia consist of vast plains of alluvium, usually much longer than they are broad, surrounded on all sides by higher ground, and in several instances having a portion of their surface covered by salt. No river emerges from any part of the Persian plateau. All the rain which falls is evaporated or absorbed. Most of the streams from the hills which surround the central plateau terminate in salt marshes or salt lakes; but there are two remarkable exceptions, the lake or marsh of Seistan receiving the Helmund river and the lake of Jotcha, which is in Russian territory: both of these are fresh.

It appears probable that the alluvial desert plains have been formed in lakes which existed when the rainfall was greater than it now is. Around the borders of the deserts are remarkable slopes of coarse gravel, formed probably of material washed from the surrounding hills. But the great depressions of the country must have been formed under different meteorological conditions, and were probably at one time river-valleys closed by the elevation of ranges of hills in the later Tertiary period accompanied by a decrease in the rainfall. The desiccation of the country has probably been gradual; it is possible that in historic times the rainfall was greater than it now is, and that the former population of the country was larger. The change has in all probability been gradual from river-valleys to enclosed lakes and from lakes to deserts.

It appears probable that a similar change has taken place throughout a large portion of Central Asia. A large part of Central and Western Asia, from the Black Sea to Thibet, closely resembles Persia in its physical characters; and the drying-up of the lower course of the Oxus may have been primarily connected with the diminution of the river due to the decrease in the supply from rain.

On the Physical Geography of the Mediterranean, considered in relation to that of the Black Sea and the Caspian. By WILLIAM B. CARPENTER, *M.D., LL.D., F.R.S.*

Taking as his datum the equality between the evaporation from the surface of the Caspian Sea, and the amount of fresh water returned to it by rain and rivers (see p. 165), the author showed the applicability of this datum to prove the correctness of Dr. Halley's doctrine, that the surface in-current of the Strait of Gibraltar is due to the excess of evaporation in the Mediterranean area—a doctrine which has been recently called in question by Prof. Huxley, who has expressed the opinion that, looking to the enormous amount of fresh water poured into this basin by the rivers which discharge themselves into it, "the sun must have enough to do to keep the Mediterranean down." The area of the Black Sea (including the Sea of Azov) and that of the Caspian are nearly equal, each being estimated at about 180,000 square miles. They lie for the most part between the same annual isotherms of 60° and 50°, the extensions of the Caspian to the south of the former and to the north of the latter being nearly equal: and hence we may conclude that the evaporation from the two seas is nearly the same. Now, as the whole water of the Volga and of the other rivers that empty themselves into the Caspian is only sufficient to make up for *its* evaporation, it is obvious that the contribution of the Danube, the Dnieper, the Dniester, the Don, and other rivers that empty themselves into the Black Sea, towards the supply of the Mediterranean, is only the *excess* which remains after compensating for the evaporation of the Black Sea—or (assuming the equality of this with the evaporation of the Caspian) the *excess* of the volume of the Black-Sea rivers over that of the Caspian rivers, which (as will presently appear) must be a very insignificant contribution to the Mediterranean in comparison with the area of the latter.

How small that excess really is, may be gathered from the experiments on the Dardanelles and Bosphorus currents, of which the particulars have elsewhere been given (p. 41). For not only is the outward surface-current extremely variable in its rate, and liable to occasional reversal, but, when it is at its strongest, its effect is most counteracted by the inward undercurrent. The proportional force and volume of the two currents cannot be estimated from these experiments with any thing like certainty; but Captain Wharton thinks that the undercurrent sometimes carries *in* as much as *two thirds* of the water that the surface-current carries *out*. That it ordinarily returns at least *half*, may be fairly inferred from the constant maintenance of the average salinity of the Black-Sea water at about half that of Mediterranean water; since it is obvious that this proportion could not be kept up unless as much salt re-enters the basin by the undercurrent as passes out of it by the upper. Hence, as the *salinity* of the undercurrent is *twice* that of the upper, its *volume* may be taken at about *one half*; so that the *actual excess* of outflow will be only about *one half* of the volume of water that forms the

surface-current. And thus the whole contribution of the great rivers that discharge themselves into the Black Sea, to the maintenance of the level of the Mediterranean, is represented by an outflow through the Dardanelles by no means exceeding the amount brought down by a single considerable river.

We now turn to the *Mediterranean,* and shall again use the Caspian as a basis on which we may form some kind of approximative estimate as to the proportion between the evaporation from its surface and the return by river-flow.

In the first place, the *area* of the Mediterranean, including the Ægean and the Adriatic, is between *four* and *five* times the present area of the Caspian; so that, taking the evaporation over equal areas of the two seas to be the same, the quantity of return that would be needed to keep up the level of the Mediterranean would be between four and five times as great as that which suffices to maintain that of the Caspian. But looking to the fact that the principal part of the area of the Mediterranean lies east and west between the parallels of 32° and 40° N. lat., whilst that of the Caspian lies north and south between the parallels of 36° and 46°, it seems obvious that this difference alone would cause the evaporation of the Mediterranean to be *much greater* for equal areas than that of the Caspian. The ordinary summer temperature of a considerable part of the eastern basin of the Mediterranean is not much below 80°: Dr. Carpenter has himself seen it ranging from 75° to 80° between Malta and Alexandria in the early part of October. And, notwithstanding the curious northern bend by which the summer isotherm of 80° is carried through Greece and Asia Minor, along the southern shore of the Black Sea, it only just touches the southern basin of the Caspian, the summer temperature of nearly the whole of this sea being below that of the northernmost parts of the Mediterranean. The difference is far greater, however, during the winter months. Taking the lowest winter temperature of the Mediterranean at Prof. Huxley's average of 48° (and Dr. Carpenter has reason to believe that this is some degrees too low for the eastern basin, whilst it is not at all too high for the western), we find the January mean of the Caspian to range from 40° at its southern extremity to 30° in its middle basin, while its northern basin is crossed by the January isotherm of 20°. Hence, as regards *temperature* alone, the mean annual excess is largely on the side of the Mediterranean. But there is another element not less important—the extreme *dryness* of the hot winds which blow over the Mediterranean (especially its eastern basin) from the great African deserts, and which take up an enormous amount of moisture in their course.

We should not be far wrong, then, in assuming that, to counteract this enormous evaporation, the volume of river-water poured into the Mediterranean ought to be *at least six times* that received by the Caspian. But what is the actual amount of that supply? Along the whole African coast, from the Strait of Gibraltar to the Nile, there is nothing that can be called a large river. Around the whole Levant there is the same deficiency. And thus, with the exception of the Nile and of the Po (a slow-flowing river of very moderate volume), no great body of water is poured into the eastern basin of the Mediterranean, save the *overflow* of the Black Sea, which comes down through the Bosphorus and Dardanelles. How small a contribution is made by this overflow to the maintenance of the general level of the Mediterranean, seems apparent from the fact that the specific gravity of the water of the Ægean, with which it first mingles, is scarcely, if at all, lowered by the intermixture of the half-salt stream which discharges itself into the part of it most remote from its communication with that larger basin. Into the western basin of the Mediterranean no other considerable rivers discharge themselves than the Rhone and the Ebro. Thus the sum total of the supply brought into the whole Mediterranean area by great rivers may be expressed by the Nile, one half of the Dardanelles surface-current, the Po, the Rhone, and the Ebro. And if we add to these the "ten submarine springs of fresh water which are known to burst up in the Mediterranean," it seems perfectly clear that we cannot make that total any thing like *six times* the amount which is brought into the Caspian by the Volga, the Ural, and the Transcaucasian rivers, and which has been shown to be *entirely dissipated by evaporation.* It has been estimated by two French officers, MM. Régy and Vigan*, who have recently compared the probable evaporation of

* Annales des Ponts et Chaussées, 1863 and 1866.

the Mediterranean with the rainfall over its area, that the annual excess of the former represents a stratum of $4\frac{1}{2}$ feet; and the largest estimate of the amount brought in by rivers cannot make up a third of this quantity *.

With such an adequate *vera causa* as this enormous excess of evaporation, there is no occasion to go in search of any other explanation for the Gibraltar in-current. For it is obvious that if the "marine water-shed" between Capes Trafalgar and Spartel were to be raised 1000 feet, so as to cut off the Mediterranean basin from the Atlantic, the excess of evaporation from its surface would produce a progressive reduction of its level (as has happened with the Caspian), until its area came to be so far restricted as to limit its evaporation to the amount returned to it by rain and rivers. But so long as this communication remains open, so long will an in-current through the Strait of Gibraltar maintain the present level and area of the Mediterranean. That this in-current persists through the winter (which is advanced by Prof. Huxley as an objection to the received doctrine) is easily explained. The temperature of the surface, though reduced to 50 degrees or thereabouts, is still sufficiently high (especially under dry African winds) to maintain a considerable amount of evaporation; and it is during the season of this *reduced* evaporation that the river-supply is least; for all the great rivers which discharge themselves into the Mediterranean basin are at their lowest during the winter months, their upper sources being then frozen up, and it is with the melting of the snows that they become filled again.

On the Physical Geography of the Caspian Sea, in its relations to Geology†. *By* WILLIAM B. CARPENTER, *M.D., LL.D., F.R.S.*

The object of this communication was to make known the most important of the facts contained in the Report of Prof. von Baer on the Physical Geography of the Caspian—these facts having a special interest for Geologists, and affording also a reliable datum in regard to the relation between the amount which is lost by surface-evaporation and that which is returned by rain and rivers.

The Caspian, which is the largest existing Inland Sea without any outlet, is a "survival" of that great central sea which, at no remote geological period, covered a large part of Northern Asia; the gradual upheaval of the land having separated it from the Euxine on the one side, and from the Sea of Aral on the other, as well as from the Arctic Sea, with which this marine province was formerly in communication. How small an elevation has sufficed to cut off this communication on the northern side, is shown by the fact, that the connexion of the Dwina with the Volga by a system of canals has opened a way for vessels to pass between the Caspian and the White Sea. Thus remaining isolated in the midst of land, the Caspian has undergone a series of very remarkable changes, which can be distinctly traced out.

In the first place, it is evident (as was long since pointed out by Pallas) that the former extent of the Caspian was much greater than its present area. The southern portion of its basin, which lies among mountains whose escarpments extend beneath the water, is by far the deepest, a large part of its bottom lying between 2000 and 3000 feet below the present surface of the water. The middle portion has also a considerable depth on the Caucasian side. But the northern portion is nowhere more than 50 feet deep; and this depth is continually being reduced by the alluvial deposits brought down by the rivers which discharge themselves into this part of the basin, notably the Volga and the Ural. These rivers run through an immense expanse of steppes, the slope of which towards the Caspian is almost imperceptible; so that if the level of its waters were to be raised even very slightly, an expanse of land at least equal to its present area would be covered by it. Now, as the present level is about 80 feet *below* that of the Black Sea, whilst ample evidence that the steppes were formerly overflowed by salt water is afforded by beds of marine shells, as well as by the persistence of

* Sir John Herschel, adopting somewhat different data, came to a conclusion essentially the same ('Physical Geography,' p. 27).

† Read in Section C.

numerous salt lakes and salt marshes, there can be no question that the northern basin of the Caspian formerly extended over the whole plain of the Volga below Saratov; and no other cause can be assigned for its contraction, than *the excess of evaporation over the return of water by rain and rivers.*

But such a reduction in the volume of water as must have taken place in order to produce this lowering of level would have shown itself, it might be supposed, in an increase of its salinity; whereas the fact is that the proportion of salt (which varies in different parts of the basin, and also at different seasons) is on the average only about *one fourth* of that which is found in oceanic water, and does not much exceed one half of the proportion contained in the water of the Euxine. This reduction, however, is fully explained by the observations of Von Baer, who traces it to the number of shallow lagoons by which the basin is surrounded, every one of which is a sort of natural "salt pan" for the evaporation of the water and the deposit of its saline matter in the solid form. This process may be well studied in the neighbourhood of Novo-Petrosk on the eastern coast, where what was formerly a bay is now divided into a large number of basins, presenting every degree of saline concentration. One of these still occasionally receives water from the sea, and has deposited on its banks only a very thin layer of salt. A second, likewise full of water, has its bottom hidden by a thick crust of rose-coloured crystals like a pavement of marble. A third exhibits a compact mass of salt, in which are pools of water whose surface is more than a yard below the level of the sea. And a fourth has lost all its water by evaporation, and the stratum of salt left behind is now covered by sand. A similar concentration is taking place in the arm of the sea termed Karasu (Black Water), which runs southwards from the north-east angle of the Caspian; for, notwithstanding the proximity of the mouths of the great rivers, the proportion of salt there rises so greatly above that of the ocean, that animal life, elsewhere extremely abundant, is almost or altogether suppressed.

This process goes on upon the greatest scale, however, in the Karaboghaz—a shallow diverticulum from the eastern part of the middle basin, which is probably a "survival" of the former communication between the Caspian and the Sea of Aral. This vast gulf communicates with the sea by a narrow mouth, which is not more than about 150 yards wide and 5 feet deep: and through this channel a current is always running inwards with an average speed of three miles an hour. This current is accelerated by westerly and retarded by easterly winds; but it never flows with less rapidity than a mile and a half per hour. The navigators of the Caspian, and the Turkoman nomads who wander on its shores, struck with the constant and unswerving course of this current, have supposed that its waters pass down into a subterranean abyss (Karaboghaz, black gulf), through which they reach either the Persian Gulf or the Black Sea. For this hypothesis, however, there is not the least foundation. The basin, being exposed to every wind and to most intense summer heat, is subject to the loss of an enormous quantity of water by evaporation: and as there is very little direct return by streams, the deficit can only be supplied by a flow from the Caspian. The small depth of the bar seems to prevent the return of a counter-current of denser water, none such having been detected, although the careful investigations made by Von Baer would have shown its presence if it really existed. And thus there is a progressively increasing concentration of the water within the basin of the Karaboghaz; so that seals which used to frequent it are no longer found there, and its borders are entirely destitute of vegetation. Layers of salt are being deposited on the mud at the bottom; and the sounding-line, when scarcely out of the water, is covered with saline crystals. Taking the lowest estimates of the degree of saltness of the Caspian water, the width and depth of the channel, and the speed of the current, Von Baer has shown that the Karaboghaz alone *daily* receives from the Caspian the enormous quantity of *three hundred and fifty thousand tons of salt.* If such an elevation were to take place of the surface of the bar as should separate the Karaboghaz from the basin of the Caspian, it would quickly diminish in extent, its banks would be converted into immense fields of salt, and the sheet of water which might remain would be either converted into a shallow lake, like Lake Elton, which is 200 miles from the present northern border of the Caspian—or a salt marsh, like those which

cover extensive tracts of the steppes—or might altogether disappear by drying up, as seems to have been the case with a depressed area lying between Lake Elton and the River Ural, which is 79 feet below the level of the Caspian, and about as much more below that of the Black Sea. It is impossible that a more "pregnant instance" could be adduced of the effect of *evaporation alone* in maintaining a powerful current, than is afforded by this case of the Karaboghaz.

That when the basin of the Caspian had been once completely isolated, the level of its water was *rapidly* lowered by evaporation, until its area was so far reduced as to keep down the amount of evaporation to that of the return of fresh water by rain and rivers, is shown by Von Baer to be an almost inevitable inference from facts of two independent orders. At the height of from 65 to 80 feet above the present level, the rocks which formed the original sea-shore of the *southern* basin have been furrowed out into tooth-shaped points and needles; lower down, on the contrary, the rocks now laid bare show no trace of the erosive action of the water; so that its level would seem to have sunk too rapidly to allow the waves sufficient time to attack the cliff-walls effectively. Again, along the shallow border of the *northern* basin, the shore for a space of 250 miles is gashed with thousands of narrow channels, from 12 to 30 miles in length, separated by chains of hillocks, which pass inland into the level ground of the steppes. In the neighbourhood of the mouths of the Volga, which brings down a greatly increased volume of water at the time of the melting of the snows, the excess flows into these channels, and thus tends to keep them open; so that, when the inundation is over, the sea again passes up them. Further to the south, on the other hand, the channels, like the intervening hillocks, are not continuous, but form chains of little lakes separated by sandy isthmuses. Although these channels run nearly parallel to each other, yet they have a somewhat fan-like arrangement, their centre of radiation being the higher part of the isthmus which separates the slope of the Caspian from that of the N.E. portion of the Black Sea. It is difficult to see how these channels can have been formed, except by the furrowing of the soft soil during the rapid sinking of the level of the Caspian water, as happens on the muddy banks of a reservoir in which the water is being rapidly lowered by the opening of a sluice-gate.

Now since, in the area of the Caspian as at present limited, an equilibrium has been established between the quantity of water lost by evaporation and that returned to it by rain and rivers (for there is no reason to believe that any continuous change of level is *now* going on), we can arrive at a better idea of what the amount of such evaporation really is, from what is needed to make it good, than we have any other means of forming. The Volga is, next to the Danube, the largest European river, and its drainage-area is enormous; the Ural is a considerable river, probably not bringing down much less water than the Don; whilst the Kur and the Araxes, which drain a large part of Transcaucasia, cannot together be much inferior to the Dnieper; and yet the whole mass of water brought down by these four rivers serves only to keep the present level of the Caspian from being further lowered by evaporation.

On the Equatorial Lakes of Africa. By Signor GUIDO CORA.

On a Portable Globe, and on some Maps of the World. By G. H. DARWIN.

On the Scientific Voyage of the 'Challenger.' By Captain J. E. DAVIS, *R.N., F.R.G.S.*

Captain Davis having briefly described the circumstances that led to the Government undertaking to send the 'Challenger' on a voyage of scientific discovery round the world, and also the ship herself and her fitting for the voyage, which, he said, were most perfect in every particular, he proceeded:—The 'Challenger' sailed from Portsmouth on the 21st of December, and on her

passage down Channel and across the Bay of Biscay encountered the weather usually met with at that season of the year.

The first deep sounding, in 1125 fathoms off, but to the southward of, Cape Finisterre, was not very successful. The second trial proved more successful, and some bright-coloured starfishes and other animals were brought to light. Another attempt at dredging was made in nearly 2000 fathoms, but whether it fouled the Gibraltar and Lisbon cable or a rock it mattered little, for after trying seven hours to extricate it, the rope broke and the dredge was lost. The 'Challenger' reached Lisbon on the 3rd of January.

On leaving Lisbon the 'Challenger' sounded in the vicinity of two rocks of 370 and 423 fathoms, and obtained 1270 fathoms near them and 1380 fathoms between them; and although the presumption is that they do not exist, still, from what I shall have to remark as I go on, it would be almost presumption to assert it; and an instance occurred the next day to bear me out in this, as in dredging off Cape St. Vincent, where the dredge was let down in 525 fathoms, the ship drifted quickly into 900 fathoms, so steep was the incline. Gibraltar was reached on the 18th; and on leaving it a few days after, proceeded in a westerly direction, in order to get on the direct line between Lisbon and Madeira, as a telegraphic cable was to be laid between the two places. It will be observed that much deeper water was obtained on the way out than at the extremity of the line. In 10° west longitude 2500 fathoms were obtained, while 60 or 70 miles west of it only 1500, with still shoaler water outside.

The 'Challenger' reached Madeira on the 3rd of February, and Teneriffe on the 5th. Leaving Teneriffe for Sombrero Island on the 14th, a course was shaped to the south-east, and when 57 miles from the peak, 1890 fathoms were obtained. The weather being fine, the opportunity was a good one for trying Mr. Siemens's ingenious differential resistance-coil. It was tested in comparison with the Miller thermometer at 100, 200, 500, 700, 800, and 1000 fathoms respectively; the difference at 100 fathoms was 2° *minus* in the Siemens, which gradually changed to 2° *plus* at 1000 fathoms. With any motion in the ship the difficulty in reading off a delicate galvanometer appears to be an insurmountable objection to this otherwise valuable instrument, and in the absence of regular thermometers could not be depended on.

The serial observations of the temperature of the ocean at various depths were now commenced. Captain Davis here described the *modus operandi* of obtaining these observations, and then proceeded as follows:—As might be expected in the vicinity of volcanic islands, there were great inequalities in the bottom, and 50 miles outside, a depth of 1945 fathoms, 1225 were obtained, and near that, to the southward, 2220, showing some steep acclivities and depressions. The bottom specimens brought up coincided with the soundings; from the shallower sounding, stones, sand, and shells were obtained; whilst from the deeper waters, *Globigerina*-ooze. The water deepened to 3150 fathoms at two fifths the distance on the section, and then shoaled to 1900 at three fifths the distance, deepening again gradually to 3000 fathoms 300 miles from Sombrero. Thus there appears to be two deep basins or valleys with a rise between them, and agreeing in contour with a few soundings obtained more to the southward. The section from Cape Verdes to Bahia will be most interesting in connexion with this part of the voyage and the two deeps ound.

Another point of observation in this line of soundings is in the nature of the bottom. In all the soundings exceeding about 2700 fathoms, the bottom is red clay, while in the shoaler water of the bank between it is ooze. The 'Challenger' anchored at St. Thomas on the 16th of March and sailed again on the 24th for Bermuda, first taking some soundings and dredging in the immediate vicinity of the islands, and then stretching away to the northward towards Bermuda.

On the 26th, when only 80 miles from the land, a sounding was taken of the greatest known depth in the world, viz. 3875 fathoms—nearly $4\frac{1}{2}$ miles. Not imagining that so near the islands so great depth of water could be found, only 3 cwt. of sinkers were used with the hydra machine; two thermometers and a water-bottle were attached to the line: the line was $1^h\ 12^m$ running out, the last 100 fathoms taking $3^m\ 18^s$. The small dredge was let down and this extraordinary depth dredged with 5 miles of rope; the dredge on coming up brought a small quantity

of mud, but with little sign of animal life. The thermometers were both broken by the enormous pressure, the pressure at that depth being equal to about 704 atmospheres, or 10,600 lbs. to the square inch. (The thermometers so broken were exhibited at the Section.)

From this deep sounding the water shoaled 1000 fathoms at a distance of 110 miles, and then continued without any great alteration until close to Bermuda, at which place the 'Challenger' arrived on the 4th of April.

The several deep soundings taken round Bermuda prove it to be a peak on which the coral animals have built the islands; and from the fact of there being considerable magnetic disturbance at different stations on the island, it may be inferred that, unlike the coral formations of the Pacific, there has been no subsidence of the mountain. There are two or three other peaks similar to that of Bermuda—for instance, the Sainthill and Milne banks, one with 100 fathoms, the other with 80 fathoms on it. These are well authenticated soundings; and had the peaks been a few fathoms nearer the surface, doubtless we should have had two islands similar to Bermuda.

The 'Challenger' left Bermuda on the morning of the 21st April. Proceeding to the north-west towards New York, the deepest water, 2800 fathoms, was found about midway between Bermuda and the southern edge of the Gulf-stream. Soon after noon on the 30th the southern edge was crossed, the temperature of the surface-water changing suddenly from 65° to 72°.

Great exertions were made to obtain a sounding in the strength of the Gulf-stream, but the strength of the current prevented its accomplishment; but conclusions were drawn from the observations made, that at this section of the Gulf-stream it is 57 miles wide and 100 fathoms deep, that the rapid part of the current did not exceed a breadth of 15 miles, and that the rate of the current is 3½ to 4 miles an hour, and that the temperature of this belt of rapid current exceeded by 3° the other parts of the stream.

On the return voyage from Halifax to Bermuda Captain Nares sounded close to the position of the Hope Bank, on which there is said to be 49 fathoms, but he found no indications of its existence.

On the voyage across the ocean from Bermuda to the Azores there is not much to comment on. The water suddenly deepened to 2360 fathoms at a distance of 60 miles from Bermuda; and the deepest water on the section was 2875 fathoms, being one third the distance from Bermuda, and then shoaled gradually towards Fayal.

The 'Challenger' reached Fayal on the 9th of July, and then went to St. Michael's, from which place she went directly to Cape-Verde Islands, and arrived at St. Vincent on the 27th of July.

On Trade-routes through Mongolia and Zungaria. By NEY ELIAS.

Three Visits to New Guinea. By the REV. W. WYATT GILL, *B.A.*

My first visit was in October 1872, when I landed on Tauan, a lofty island separated from the mainland of New Guinea by a strait 4 miles wide. Near to Tauan, and formerly considered to be a part of it, is the low, fruitful, unhealthy island of Saibai, 10 miles in length. The interior of Saibai is a vast morass, with myriads of snipes, curlews, &c. The inhabitants are a fine Negrillo race, very suspicious of strangers. On both this and the adjacent island the houses of chiefs and warriors are ornamented with strings of skulls of New-Guinea Bushmen. In the principal village of Saibai stands a lofty cocoa-palm, with two branches growing out of the parent stem at the same point.

A few days afterwards we steamed on to Katau, a village on the south-western coast of New Guinea. The coast was covered with stately melancholy mangroves, very unlike the scrub bearing the same name in Queensland. A conical hill some miles inland alone relieved the monotony of the scene. The navigation of this unsurveyed coast is most critical, owing to the presence of coral-reefs and sunken

rocks. The dwellings composing the village of Katau are but few in number, but of immense length. They are built on piles, with end verandahs, and thatched with the leaves of the sago-palm. In one village we entered a dwelling with sleeping accommodation for upwards of sixty couples! Tobacco is largely cultivated. The pipe was 33 inches in length, consisting of a piece of bamboo with a movable bowl. The fumes are inhaled. Our interpreters secured a good reception for us wherever we went.

A second or eastern mouth of the Katau river was discovered as we pressed on to the village of Torotoram, which is larger than the village we had left. To get to it we had to wade more than half a mile over a bank of fine black sand. On our arrival we found that the entire population had fled into the bush with all their valuables, excepting four or five men, who stood doubtfully in front of a house watching the movements of the strangers. As soon, however, as it became evident to these scouts that no hostility was intended, the whole male population returned. Not a woman, a child, or a decrepit man was seen during our visit.

This part of New Guinea, from the western limits of the Katau district to Bristowe Island, is called Mauat by the natives and by the Torres-Strait Islanders. Opposite Bristowe Island is a deep navigable river, half a mile across, supposed to be a branch of the Fly. The aborigines of this part of New Guinea call their great island *Daudai*. Torres-Strait Islanders corrupt this into *Daudi*. Australia is known as *Great* Daudai, New Guinea as *Little* Daudai. Although upwards of seven weeks were spent in New Guinea waters, never once did we hear this famous island called "Papua."

Two small rivers empty themselves into the Straits opposite to two islets not marked on any chart.

A second visit was paid to Mauat about a week afterwards. The same feeling of cordiality prevailed as at the first. One of our party walked into the bush for two miles amongst luxuriant plantations of bananas and taro. The country was a dead level, the soil of the richest description. The bread-fruit-tree grows luxuriantly. Kangaroos, a peculiar species of hog (*Sus papuensis*), dingos, opossums, and cassowaries abound. At first sight we mistook several highly polished leg-bones of the "Samu" (cassowary), used for husking cocoa-nuts, for human bones.

Some miles to the west of Mauat lies Baigo, or Talbot Island. The inhabitants of the mainland near Baigo are numerous, but by no means to be trusted.

On the 19th of November, 1872, we started from Mer for the eastern peninsula of New Guinea. We sailed through Flinder's Passage into the open Gulf of Papua, thus leaving awhile the most extensive coral-reef in the world, inside of which we had been sailing for two months. Two days afterwards we sighted the lofty mountain-range which forms the backbone of the peninsula, affording a striking contrast to the low south-western coast. A great number of palms were seen drifting with the current, the stems and fronds covered with sea-birds. The appearance of Yule Island was very park-like, clear grassy spots alternating with picturesque clumps of trees. The island is 4 miles in length, and of considerable height. Early on the following morning we anchored in Redscar Bay, close to the islet of Varivara (the Parivara of the charts).

The inhabitants of the little hamlet of Kido were timid, but very pacifically inclined. On the following day we discovered the river and village of Manumanu. The village consists of ninety-four houses, with a population of about 1000. The houses are two-storied, and are all built on high stakes. The women are exquisitely tattooed, but the men not so extensively. The complexion of these people is nearly the same as that of the Samoans and Rarotongans, but in stature and physical strength they are much inferior. Many words are identical in all three dialects, proving them to be essentially one. It is impossible for any one who has seen these pleasant, gentle, light-skinned natives of Manumanu to doubt that they are of Malay origin.

Manumanu river (erroneously called the "Towtou" in the charts) is over a mile across at its mouth in the driest month of the year. We ascended the river to a distance of 7 miles, but found the country everywhere to be an immense swamp. Just beyond is the first interior native village, named Koitapu.

A most interesting fact is now for the first time ascertained, viz. that *Manumanu*

is the last village on the coast inhabited by the light-coloured or Malay race; so that from Manumanu river *westwards* the Negrillo race alone flourish, the Malays inhabiting the whole of the eastern peninsula of New Guinea.

Notes of recent Travel in Persia. By Colonel Sir FREDERIC GOLDSMID, *K.S.I.*

The paper commenced with a review of Persia at the present day, according to geographical limits, as compared with Persia of the past, arguing that it may be said to comprise now quite as much settled and consolidated territory as at any period of its political existence of which we can speak with the authority of intimate acquaintance. If she has less extent of land than before her latest disastrous war with Russia, there is, at least within her recognized limits, less rebellion and more allegiance. Allusion was made to the various works of reference on the country, from those of Tavernier and Chardin up to the existing time; and it was asserted that to the nineteenth century we were indebted for the most important additions to our knowledge of the geography and people of this part of Central Asia. As regards the diplomatic relations between Persia and the European states, there was practically none of these had more to do with her than England. We no longer sent our commissioned officers to teach her the art of war, but we had for nearly ten years supplied her with commissioned and non-commissioned officers of engineers to direct and maintain her lines of telegraph. By Convention of November 1865, this number was raised to fifty. Since that period the number was increased. In the very recent Convention no specification of numbers of *employés* is made at all; and a plain straightforward agreement for maintaining and working the line has been accepted on both sides for a further term exceeding twenty years.

The routes more particularly described were those traversed by the writer from Resht to Tehran, from Bushahr to Tehran, and from Mash-had to Tehran. The first might be stated generally as one fourth low forest, one fourth mountainous, and one half a tolerably level plain. To Kazvin the scenery is very varied; but the latter town, although it has a telegraph-office and post-house, and is interesting in its history and remains, as an abode of civilized life is orderless and methodless. From Bushahr to Tehran, the first section of the road, or 170 miles, commences with a low marshy coast, and rises to a height above 7000 feet among noble mountains, ending at a lower but still respectable elevation at Shiraz. The second section is of 265 miles, to Ispahan, and is interesting from the ruins of Persepolis and other monuments of antiquity, as well as mountain scenery and the presence of "Iliāts" or wandering tribes. The third and last section of 250 miles, to Tehran, has for its attractions the charming mountain-station of Kohrud and the cities of Kashan and Kum; but between Kum and Tehran is a desert not inaptly termed that of "the Angel of Death," so utterly blank and desolate does it appear. From Mashhad to Tehran there are here and there pleasant or interesting halts; but the greater part of the 540 miles is monotonous, and some 60 to 100 miles are infested by the Turkman hordes.

Some account was also given of the cities of Tehran, Ispahan, Mashhad, and Kazvin, and the following extracts may have interest as conveying recent and original impressions:—

"I should not say that life in Persia was generally suited to Europeans; but it promises, at least, to be more so as intercourse progresses, for the drawbacks are rather social than physical or external. In the north, except for two or three summer months, the climate is agreeable enough, and even at the hottest time it is seldom that the nights are oppressive. To those who come from India direct, or to whom Indian heat is habitual, the change is most delightful. There are days in autumn, winter, and spring which leave the impression of unequalled temperature; and the blue sky, with its tempering haze, as it were a veil of reflected snow gathered from the higher peaks or ridges of continuous mountain-chains, is too exquisite a picture to be readily forgotten. In the late spring Fashion moves out a few miles from Tehran to the cooler residences near the mountains, returning in the late autumn to the precincts of the capital. These, it may be noted, have been considerably extended of late years, and are designed for yet further extension. . . .

"Persian houses are not comfortable, in the English sense. Although the character of native Persian domestic relations involves separate suites of rooms, there is no privacy in any department; for the women's part is as much frequented by women and children as the men's by the ruder sex of all ages and classes. Servants, unless kept away by order (a dangerous process with the idler ones), are apt to be ubiquitous, and turn up at all hours of the day about the house, noisily bickering, listlessly squatting, or moving with silent solemnity. Visitors used to give notice of coming, but are gradually and tacitly abrogating the practice; and natives and Europeans will soon, it is presumed, call upon each other in Persia with as little ceremony as elsewhere. Nor is it unlikely that the habit of bringing tea, coffee, and pipes to every visitor will also fall into disuse. The old orthodox custom of a threefold supply is, to say the least, inconvenient; for strict fulfilment of a dozen visits would necessitate the absorption of thirty-six cups of warm liquid and thirty-six 'sets' of tobacco inhalations."

The paper, moreover, contained many particulars and some statistics of the late disastrous famine, gathered during the last two of the three journeys above mentioned.

On a Visit to Koh-Khodja. *By* Major Beresford Lovett.

On Assam, and an Overland Communication with China.* *By* J. M'Cosh, *M.D., late H.M. Bengal Army.*

The subject of this paper is an overland communication between India and China, between Assam and Yunan, between a navigable branch of the Brahmapootra and the Yang-tsi-kiang, between the two most populous empires in the world—the one numbering 200,000,000 inhabitants, the other 300,000,000. The author spent the early part of his service in India, in Assam; and wrote its topography, a book published by order of Government. After giving a bird's-eye view of Assam and its surroundings, its people and climate, of the discovery of tea in the province, and the rise and fall of its tea-plantations from want of labourers, he proposes a route direct across from the Brahmapootra through Munnipoor and Upper Burmah to Bhamo, and thence on through Momien and Talifoo to the Yang-tsi-kiang. Such a road, even a footpath, if protected by the Chinese, the Burmese, and the Indian Governments, would afford a ready outlet to the surplus population of China, and be the means of restoring prosperity to the bankrupt tea-plantations. Moreover, he expresses a hope that at no distant day the North-eastern Railway of Bengal shall be extended across from the Brahmapootra to the Yang-tsi-kiang in the same direction, when the immense trade of the Indus, the Ganges, and the Brahmapootra, the Ningtee, the Irrawaddy, and the Yang-tsi-kiang, shall be hoisted on trucks, and rolled from East to West and from West to East in one grand tide, and that the British merchants shall fill their pitchers from the stream, and deal out its bounty to the people of the land.

On Recent Arctic Explorations. *By* Clements R. Markham, *C.B.*

On Discoveries at the Eastern End of New Guinea. *By* Captain J. Moresby, *R.N.*

On Russian Accounts of Khiva and Turcomania. *By* E. Delmar Morgan.

On a Journey from Peking to Han-kow. *By* E. L. Oxenham.

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* The original has been printed *in extenso* by order of the Secretary of State for India.

On the Distribution of Coal in China. By Baron von Richthofen.

Survey for a Telegraph-line between Berber and Souakim. By Captain Rokeby, *R.E.*

On Trade-routes in Persia. By Major St. John.

On the Livingstone East-Coast Aid Expedition. By Major Evan Smith.

A few Notes on the Trade of the East-African Coast. By Major Evan Smith.

The Gorges and Rapids of the Upper Yangtsze. By J. Thomson, *F.R.G.S.*

Mr. Thomson ascended the Yangtsze in the beginning of 1872, having for his companions two gentlemen, Captains of steamers in the China trade. The party left I-Chang (a city on the left bank of the river, about 1100 English miles above Shanghai) on the 7th of February. They engaged a native boat with a crew of twenty-four men, and proceeded to ascend through the gorges of the Upper Yangtsze. The river was at its lowest, and in the I-Chang gorge (which is entered fourteen miles above the city) the great river was left, in many places, with a waterway of only 100 yards wide between gigantic walls of rock. Mr. Thomson next proceeded to describe the appearance of the I-Chang, Lupan, Mitan, and Wushan gorges, and the difficulties and dangers to be encountered in the future steam-navigation of this section of the Upper Yangtsze, where there are many rapids interspersed with jagged rocks, on which the native trading-boats are frequently worked. The most formidable rapid was below the village of Isingtan, at the mouth of the Mitan gorge, where it was customary with the Chinese traders, before making the ascent, to unload their boats and have the cargo carried overland to the top of the rapid. The grandeur of the mountain- and river-scenery at this part of the journey was minutely described, as well as the appearance presented by the rapid. The author was here aided by the valuable accessory of a large photograph, which he had taken on the spot. This and other pictures were obtained at some personal risk, as Mr. Thomson was stoned and otherwise treated as a very rare and dangerous type of "Yang-quitsz" (foreign devil), who had come among them with his picture-taking instrument to extract the secrets out of heaven and earth. Fond mothers seized their children and carried them away, as it was popularly believed that the solutions used in taking the photographs were made out of the tender eyes of Chinese children. In the open spaces between the gorges the temperature was found to be several degrees lower than in the mountain-clefts which form the gorges. The rapid of Isingtan was running about nine knots, "and yet the Chinese traders find no obstacle in this, or indeed in any of the other rapids of the Yangtsze, to the carrying on of a lucrative trade with large-sized cargo-boats." These boats, and their appliances for warding off danger, were badly constructed. Mr. Thomson argues that if the Chinese can do all this, we, with science, suitable steamers, and pluck, can do more. "Let the river be opened, and its successful steam-navigation will follow."

Some interesting details were furnished regarding the working of coal-mines in the province of Hupeh. Several mines were visited; and Mr. Thomson succeeded in taking a series of photographs of Chinese coal-mining The paper concluded with an account of the ascent of the Wushan gorge.

ECONOMIC SCIENCE AND STATISTICS.

Address by the Right Hon. W. E. FORSTER, *M.P.*, *President of the Section.*

[Spoken on Monday, September 22nd.]

YOUR Council have asked me to take the responsible and honourable position of being the President of one of your Sections. I am quite sure that that honour cannot have been conferred upon me owing to any special fitness on my part, but rather from two facts—the one that I do happen to have taken an interest in the questions that have come before this Section for many years, and the other that I am a Bradford townsman and a Bradford Member. As a Bradford man I was so glad to do what I could to welcome the Association, that I felt I could not refuse ot try to perform any duty that was imposed upon me; but I must acknowledge that in attempting to do so I have found special grounds of unfitness. The fact is that my time and thoughts are so occupied with other pressing matters that I really have not been able to prepare this address with that care and thought, or to bestow that pains in expressing what I have to say, that I know is due to so distinguished an audience. I merely make this remark (for I do not want to take up your time by apologies) to explain why I have not followed the usual course and brought forward a prepared written address, and why I have thus been obliged to ask you to let me make a speech instead of reading a paper. I do not deny that the accident of my being connected with the Government does not specially fit me for this duty. In this Section we deal, and we must deal, with politics. Under our title, that of Economic Science and Statistics, there is hardly any question of political discussion, hardly any immediate question of pressing legislation, which may not be brought within its deliberations. And that has been proved by you; for if you look at your own 'Journal' you will see that such political questions (pressing questions, and I may say burning questions) have been successively brought before you, as the question of the income tax, the amalgamation of railways, education (of which last I am not unconscious of the difficulties), and many other matters that excite great interest and might be made use of, but I am quite sure they will not at this Association be made use of, for party purposes. But it certainly, as a general rule, does not become any man who happens to have the honour of being a member of the Ministry to make suggestions with regard to political measures, unless he is prepared to bring them forward, and press them upon the responsibility of Government. It rather becomes such members of the Ministry to hear suggestions, to listen to them, and carefully consider them. A man who is a member of the Cabinet must also recollect that he must consider his colleagues, and must be very careful to say nothing that will commit them. However, care in these matters may be pushed too far; and as I am here now all I can do is to ask you to forget, as I have tried to do, that I am connected with the Government, and to remember that in what I now say I commit no one but myself. I think this question will occur to many of you, as it did to me—Why, in this Association, do we deal with politics? What business have we to have such a Section as this? why should we discuss political matters? what has the discussion of politics to do with the meetings of a scientific congress? There is an immediate answer to this question; and that is, that after all there is a science in politics. If the political theorist—and I do not use the word as a word of reproach—but if the political thinker misconceives or misstates or mistakes his facts or his statistics, he as surely fails in evolving any thought of value as does the student of physical science who generalizes from a partial or imperfect series of experiments. In like manner, if the practical politician, in attempting to apply the principles of economic science, breaks the laws of that science (for instance, the laws of political economy), the result will be that he will pay the penalty in the failure of his political measures, as certainly as does the practical mechanic or chemist who ignores the laws of chemistry or those regulating the application of mechanical forces. But it may be said that although this is true, such is the immense range which our Section would extend over, that there would be a danger in its taking up too much of our attention, and that these subjects had better be left to the kindred Association

which was started as the great development of our Section—the Social Science Association, of which my noble friend Lord Houghton will be chairman on an early day. But I do not think there is any danger of our monopolizing too much attention. After all, a very large number of members of our Association are those who act with great knowledge and interest in physical science, and who with great power give information and show anxiety to hear what their fellow members have to tell them. But I should be sorry to see this Section omitted from our programme. I think there is great advantage in bringing together men of science and politicians. Perhaps one result of this may be that we shall obtain higher scientific culture. I wish that this may be the case. Over and over again in the work I have felt it my duty to try to do, I have lamented my own scientific ignorance. I have felt, and I have no doubt others who have attempted it have also felt, that we could act more successfully if we knew more of the laws of nature. There is hardly any fact in human intercourse, hardly any influence which a man can bring to bear on his fellow men that might not be explained, illustrated, and enforced by some analogy of outward nature—that has not, as it were, its counterpart in the workings of nature, in the eyes of the man who is fortunate enough to have some real knowledge of both men and things. Again, there is undoubtedly an advantage in subjecting political questions to the conditions of scientific debate. It is well that they should sometimes be treated and debated in that temper and with that simple desire for the discovery of truth which ought to characterize all scientific discussion. Then, again, as regards this special Section there is an advantage in the political theorists or thinkers being brought into contact with the practical politicians; for when they come together I think the theorist would perhaps learn to appreciate and estimate more fairly than he sometimes does the immense friction, if I may use the term, with which the practical politician has to deal, and which he finds to clog and interfere with his efforts. It is not sufficient to enounce and explain the laws of economic science. In outward nature you have to deal with dead facts. In economic science, affecting the political and social condition of men, you have to deal with persons who have free will and the power of exercising it and of refusing to obey the laws which you explain; and we none of us can forget that we have to contend with and to take account of the likes and dislikes of men, and the passions and even the prejudices of men, and that it is not enough for a State to declare the laws of economic science—of political economy, for example. We must not forget that many men will not obey these laws, however clearly we may explain them and point out the penalty of their transgression. Sometimes they disbelieve in the penalty; often they ignore it; and not seldom, knowing its existence, they prefer to incur it. We must take into account the existence of this friction, and we must be prepared for this result—a very disappointing result, and a result of which I am sure experimental philosophers would greatly complain if they were beset with it in physical science; and that is, that though just in proportion as in any political measure the laws of economic science are broken, there will be weakness, and probably failure in that political measure, it by no means follows that just in proportion as the law is kept and adhered to there will be success. It is not seldom the case that by its very truthfulness a measure excites so much opposition that it ensures its own defeat. Well, that is a reason which thinkers ought to bear in mind when they sometimes accuse political men of delaying to bring forward measures of which they are convinced. It is a ground, and a reasonable and proper ground, very often for the postponement of a political measure based upon true principles Those who are most in favour of such a measure and most advocate it, feel that they are doing it harm by prematurely bringing it forward; but some persons push that doctrine too far, and say that it is a reason and an excuse why a measure should be brought forward upon false principles. Now that I do not admit. I believe that nothing really is gained, though something may sometimes seem to be gained, by any man bringing forward a political measure upon principles in which he himself disbelieves. He may be quite sure that in the different opinions of men, if it be at all desirable that such a measure should become law, there are plenty of people (if he will simply drop behind and not do that of which he disapproves) who will come forward and advocate it who do really approve of it.

But I must now, after these prefatory remarks, go to the special work of this

Section. I believe it is usual for the President to refer in his address to the progress of Economic Science for the past year. Well, I think you will hardly expect me to do that. If I were to refer to the progress of Economic Science, I should have to show to what extent, amongst other ways, it has been put forward or not in legislation; I should have to defend the Government against charges that might perhaps be made of its not having been put forward. Well, I believe that you will feel that I should be taking a very unfair advantage of the post I occupy, and of the duty you have kindly imposed upon me, if I were to make this an opportunity of defending the Government. And, in fact, I cannot forget that one very important branch of Economic Science would be considered to be that with which I am myself connected—that of education; and if I were to attempt such a review it would necessarily partake of a much more personal character than I should desire. I therefore resist the temptation, although I do not deny that it is a temptation when I have before me such an audience as this, to vindicate the principles upon which, on behalf of the Government, I have acted—or, at any rate, to explain (and I think I should be able to explain with success) the fact that we have acted upon principles, and not upon motives of expediency. But, talking of a review of progress, I should be exceedingly glad if I were able to make any full statement of the progress which has been made in the economic condition of the English people—not for the last year only, for we cannot judge by such a short period, but for a longer time, say from the time when this Section was first formed, which I believe to be about forty years. Now what, after all, is the great object of our deliberations in this Section? Why do we collect and test and analyze statistics? and why do we study the principles of economic science, and the mode in which those principles are and ought to be applied? Many would reply mainly in order to promote the economic well-being of the great mass of the community. Well, I should be exceedingly glad if some member of your Association, well qualified to do so, would consider whether, at some forthcoming opportunity, a careful comparison could not be made as to the economic condition of the great mass of the English people at this time as compared with what it was forty years ago. I have not made that comparison, I have not had time to collect the necessary statistics; but I think this statement will hardly be challenged, that (take for example the condition of the manual labourers of the country, which is after all the largest class of the community, and must continue to be so) there has been progress the most hopeful for the future, and the most remarkable as compared with like periods in the past. I do not think it will be denied that the great body of manual labourers throughout the country have a greater share of the comforts and enjoyments of life than they had forty years ago; that they are able to obtain more of the necessaries and comforts and even of some of the luxuries of life; that their wages are higher (on which point I would refer you to the paper read yesterday by Professor Leone Levi, bearing in some measure on this matter)—not only higher in themselves, but also as compared with the cost of living. There was great reason that they should be higher. The higher rate, too, is earned with shorter hours, and by labour, generally speaking—I won't now speak of every trade, but generally speaking—under improved conditions from those which existed at the former period.

Passing from these purely material conditions, much as there is yet to do in education, no one will deny that there has been progress in education. No one, I think, will deny that there has been progress in general culture; and, speaking generally, I believe there has been great progress in better and more kindly relations between this large and important class and other classes of the community. Well, now, I should be very sorry if these remarks were misapprehended. Do not suppose me to think that in stating my belief that there has been progress that we have got to that point at which we can rest and be thankful. I should be very sorry to be supposed for a moment to be suggesting apathy to ourselves in our endeavours to improve the condition of the manual labourer, or suggesting or advising content to him—if by content be meant a cessation of efforts for his own improvement. I believe there is much in the conditions of labour and the state of manual labourers throughout the country to which the word content would be by no means applicable. There is much for others to do for them, and still more for them to do for themselves. I merely mention this progress as a stimulus for the

future, not as any ground for rest. This is not the place or the time to dilate upon what labourers can do for themselves; and all I would say on that matter is that when any of us are advised or speak against what we may think to be the besetting sins of the labouring class, we ought never to forget what are the besetting sins of our own class. We must also recollect that in the present state of civilization we must make a great distinction between crime and vice—remembering that crime and vice cannot be attacked in like manner. We must continue to punish crime, to bring force to bear upon it; but as regards vice (and I include in it that great and terrible vice of drunkenness) I believe we shall be obliged to admit that the time has long passed (indeed I doubt when it ever existed) in which we can attack vice with success by force, or by any means but persuasion. As regards, however, what can be done by others, by such a Section as this, by the Legislature, for the condition of the manual labourers, I believe that, notwithstanding what has been done, very much more may be done.

I alluded to what appears to be, speaking generally, the improved condition of the labourer—that is to say, by the help of scientific discoveries man fights nature with less suffering to himself. There are many of us who can detail the beneficent results of scientific discovery in one case after another. All I will say is that I believe these conquests over nature are but the prelude to future triumphs, and that I look forward to these great and beneficent results being still more apparent in the future than they have been in the past, from the thought and experiments of scientific men—that they will enable the products of nature to be realized for the good of men with less suffering to the individual worker. Take, again, the advantages of free trade; and what, after all, is free trade but the simple carrying out of scientific laws? It means nothing else. There was a dispute in old time as to whether the manual labourer would gain by free trade. No one would now raise that dispute for a moment. Not only English labourers have gained, but, from our having learnt the lesson and having adopted the principles of free trade, even the labourers of other countries where they have not learnt these principles have shared in the advantages of free trade, which we in these great centres of commerce have made our own. I do trust we may now see grounds for supposing that other nations are learning from our example; and as their working men have gained by what we have done, so our working men may gain by what they will do. I can hardly avoid making one allusion to an event of the past year—to the very encouraging support of free trade shown by the action of the French Government. To the Emperor Napoleon we have all been grateful for using his power for the encouragement of free trade, and we have to acknowledge his patriotism and his fidelity to knowledge, and to truthful political philosophy, in establishing some encouraging principles of free trade in France; but we know that they were forced upon the French people, and we did not know what they might do when they had freedom. But in that matter they have had freedom to do as they thought best, but in conditions of disadvantage to free trade. The Government (though they had a great statesman who was not himself convinced upon the matter, and who had great influence) in the past year declared themselves decidedly in favour of free trade. I cannot doubt that that fact will have taken hold upon men both in the United States and elsewhere. But economic science does not apply merely to the interchange of commodities between nations, but to the interchange of all matters of value. I think we feel that its principles must be enforced and carried out both with regard to land and to labour. There should be nothing in law whatever which should prevent the most entire freedom in selling and buying land; this principle can hardly be disputed, and its mere statement is almost sufficient to encourage us in the reforms that will be necessary to carry it out. The same principle applies to labour; there must be freedom to sell it and freedom to buy it. Then, again, I suppose sanitary improvements must be considered to come within the range of our Section. Well, there is much, very much, to do in that matter. I think our aims in this direction are higher (and I take comfort from the fact) than they used to be. We are aiming not only at preventing death, but at making life better worth living, by making it more healthy; and we no longer forget that in fighting our battle against disease it is not those only who are killed that are to be considered, but also the wounded. In the terrible inflictions of preventible disease throughout the

country the loss of life is very sad; but even more sorrowful, to my mind, are the numbers of our fellow creatures (fellow countrymen and women) who are doomed to struggle and fight the battle of life under the most severe conditions because of the wounds they have received from preventible diseases. And on a matter like this you will at once see the advantages of this Section. It is most desirable that all those projects for sanitary improvement which are proposed by political thinkers or by practical politicians should be at once tested by scientific laws, and by men who are accustomed to make these laws their special subject. I will not say any thing more about my own particular Section; I would merely refer to what I ventured to say after the able address of your President on Wednesday evening. I would, however, refer to the discussion yesterday on the papers read by my friends Mr. Morris and Professor Leone Levi with reference to our expecting in the increased well-being of the community a greater diminution in the pauperism of the country than we yet see. I believe there is a diminution, and I am hopeful that it will be shown to a greater extent in a short period. But I am rather anxious (I may be thought by some rather heretical in what I am going to say) that in our objection to the evils that accompany a poor law we should not carry that objection to the extent of imagining that we could do without any poor law. The objections to the poor law lie upon the surface. I fear it is true that it does encourage a want of thrift, and to some extent does deaden or weaken and make less likely the performance of domestic duties. And there ought to be very great reason for the poor law if it be possible to make this charge. I think there is great reason. I do not believe that in the present state of civilization it is safe or right not to acknowledge the principle of the poor law—namely, that a man shall have a right to live, and that absolute destitution shall be prevented. Very few of us are aware of the advantage that the acknowledgment of this principle has been to us. In comparing our social struggles (our political convulsions) in England with those of the Continent, I believe that the one great reason why we have got through them with comparative safety, and have had reform instead of revolution, has been that the large body of our people have known that this right is acknowledged—the right to live.

Going back to the progress to which I have referred, we must bear in mind two facts. Those of you who have studied political economy and are familiar with the writers on that subject of twenty, thirty, and forty years ago, will remember that they almost all supposed that there would be no great improvement without an increase in the population, or at any rate without a great decrease in its increase, if I may so put it. Mr. Malthus, Mr. Mill, and many other most able and excellent political economists, advocated very strongly what they called a prudential check on population as the only means, or the most probable means, of making progress in prosperity. Well, but our progress has been made without this check and in spite of the great increase in population. I am a bad statistician, but I believe the increase during the last forty years has been greater than in almost any other previous term of forty years. The increase in the population of England and Wales, in round numbers, has been from sixteen and a half millions in 1831 to twenty-one and a half millions in 1871, and yet the population is more prosperous. Again, if there has been great progress on the whole in the well-being of the labourer, there has also been progress in the well-being of the capitalist. I am not going to speak of the special profits of special trades, but I believe it would be easy to prove that the increase of capital in this country has been much more than has kept pace with the increase of population. Well, if both classes, capitalists and labourers, have on the whole bettered their condition, I am not at all surprised to find that there is, as I believe, a better feeling between the two. I hope my friend Mr. Morris, if he is there, will let me make some allusion to his able paper of yesterday. I do not agree with all his views; but I wish to treat them in the same spirit with which he treated the views of others—a spirit of fairness and willingness to appreciate what could be said on the other side. I am aware it is by no means a rare feeling, but a very common feeling at this time, that the disputes between labour and capital are more dangerous and more fierce than they were at former periods. I must demur to this statement. I think it may be true that these disputes are sometimes carried on upon a larger scale than formerly, because

the number of labourers is greater now, and the power of communication is much easier; but what I venture to say is this, that these disputes are conducted with much less fierceness and acrimony than in former times. I also believe that they, generally speaking, do not last so long. For instance, there are some Bradford men, I suppose, who can remember the fierce struggle there was against the introduction of machinery into Bradford—the violent fights that there were at that time, though it would be almost impossible to have any thing of that kind in Bradford now. Again, I can recollect almost as a boy I was learning a manufacturing business at Norwich, and there was a dispute, and the masters had to walk through the town looking with suspicion at almost everybody that was coming near them for fear of having vitriol thrown into their eyes. That, again, is a state of things that has long passed away. Again, take the Preston strike of twenty years ago, which I studied somewhat keenly. That was a struggle that lasted longer than almost any dispute of modern times; and I must add my conviction that there is not now that foolish struggle against the laws of science that there was in former times.

Well, then, as I demur to my friend Mr. Morris's statement, he will not be surprised if I say that I demur to the remedy he proposed at the close of his paper. I think he overrates the evil; but whether he does so or not, his remedy (a league of capitalists and capital throughout the country) is one which I should be most grieved to see any attempt to apply. Whatever individual labourers may advise their fellows, I believe that in this country, where the interests of the labouring men are so varied, however it may be advised, a league of labour against capital is impossible. There may be talk about it at meetings, and there may be talk about it in the newspapers, but I do not believe in its possibility, though, if any thing could make it possible, it would be a league of capitalists against labourers. I think we shall agree that two such opposing leagues would be one of the greatest calamities from which the country could suffer. I should tremble at the thought of our industry being divided into hostile forces, and all the industrial workers of England being distributed into opposing camps. Some persons would say it is impossible, because the capitalists and labourers would be so unequally matched in power—that now you have given votes to the labourers, their numbers and the power of their votes would make them so much stronger than the capitalists. Now, I cannot take that ground myself. I think if the two parties were unwise enough to band themselves in opposition (a thing which I believe they never will do) they would not be so unequally matched. I believe that money will always buy men, and capital always find support amongst labourers. I believe they would not be unmatched in power; and although I know very well that my friend and others only mention such a remedy for extreme occasions, and would advocate it on the fairest principles, I believe that if the contest once took place it would be conducted with equal recklessness on both sides. Under these circumstances I take some additional comfort from one political measure with which I have had something to do. If there was any thing like such a struggle between classes throughout the country, there would be such a disposition on the side of each party to clutch the power of the law, and to aim at legislative measures as cannot but make me feel glad that the Government of which I am a member have done something towards bridling the power of the leaders on each side by giving to the voters the protection of the ballot. And this brings me to one remark which perhaps you will allow me to make, and it is this: that, putting aside the possibility of these opposing leagues (and I dismiss them from my mind), I think that on both sides (those who advocate the rights of labour and those who advocate the protection of the rights of capital) there is a little too much anxiety to make use of the law. No doubt there should be perfect freedom in selling labour, and that implies that there should be perfect freedom in combination. I believe there was no greater mistake than the attempt to prevent a man from agreeing with his fellow workmen as to the conditions upon which he should like to sell his labour. But, of course, we should also say that there should be perfect freedom to refuse to combine, and that such right should be respected and protected. But in our effort to secure that freedom we must not try to get the law to do that which it cannot rightly or in fact effectually do. We can make use

of the law to protect the Queen's subjects against bodily harm and physical violence, but it is no use attempting to protect men against persuasion or even against moral intimidation. They can only protect themselves. And if the law attempts or strives to do that it will surely fail, and probably lead those against whom the attempts are exercised to think that there is a desire to interfere by recourse to the law with their reasonable freedom. And I think, in dealing with this question of the law, we should not have recourse to exceptional legislation. To illustrate that I may say that very few things have been done by the House of Commons that I so much regret as the way in which we dealt with trades unions at Sheffield. I think the law we passed (in order to get at information with regard to trades unions at Sheffield) to obtain an available blue book as to what had been done at Sheffield was one much to be regretted. We issued a Commission, and we stated that every man, whatever he had done, might come before that Commission and give evidence perfectly free from any of the consequences of the crime he had committed. What was the result? That we had men who had been engaged in the plotting and planning of deliberate murder, who came forward and stated what they had been guilty of, and then there was the declaration of the law which saved them from the consequences of their crime. That did not apply merely to the case of King's evidence, where the least guilty would be saved, and the more guilty punished; but it was a paltering with the law, applying as it did to all who were guilty, affording as it did protection to the murderer, and that in order that we might acquire information on which to found exceptional legislation. Such a step will, I hope, never be repeated. Our real hope in this matter must be that which has caused what I conceive to be the progress that has been made, namely, the effect of public opinion and education—the slow result of the proclamation of truth as to the relations of labour and capital. By these means alone we can hope to solve the difficulties which exist; and I cannot but think that such a Section as this will be a most useful aid in this important work. I may be told that this hope is rash when we see the extraordinary ideas which are propagated in Congresses, and reported day by day in the newspapers. Well, I have read with great interest what has been said in Geneva at both these Congresses, and I have observed this encouraging fact, that hardly any Englishmen have taken part in them; and that, when they did, it was on the side of good sense, and to denounce wild and impracticable ideas. But this is not the first time that we have had these notions declared before us.

My noble friend Lord Houghton and myself, in 1848, were in Paris, where we amused and interested ourselves by trying to learn what we could of French notions at that time about the relations of society, especially of labour and capital; and I am sure the ideas which we now think strange were then stated with even more extravagance, and I think with much more agreement among the general public than at this moment. The Commune of Paris may be quoted: but I do not think it is a fair illustration. The Commune had its sad crimes: of that I fear there can be no doubt; but these crimes and its very existence were not so much the effect of French notions with regard to Communism They were rather a reaction against the central and severe despotism which had prevailed in France, destroying, as it were, all local powers and trying to crush out local life. I believe that a vastly larger number of working men are admitting now what we consider to be the fundamental facts of political economy than was formerly the case. We find they will now generally acknowledge that there are after all only three ways by which labour can be better remunerated. The first is by the increase of capital—of the wages fund. The second is by the diminution of labourers, either by emigration or by a diminution of population, and that not simply by the diminution of labourers in a special trade: that is a mistake which they still sometimes fall into; it may appear to relieve a trade for a time, but it only does so by driving more labourers into some other trade—making that trade unremunerative or less remunerative to the labourer, and thus bringing him back to the trade which is more so. The only way in which they can hope for a remedy under the second head is by a diminution of labourers generally. The third way in which the conditions of labour may be improved is that by which the labourer may himself become a capitalist. Our recent progress has been made almost entirely in consequence of

the action of the first principle I have named, viz. by the effective industry of the country—the capitalist and labourer working successfully together, and thereby making an immense increase in the capital and in the labour fund: but I think that all attempts to better the conditions of labour in the third way (that of the labourer becoming capitalist) are most interesting, most hopeful; and it seems to be a special business of such a Section as this to watch the attempts to carry out these experiments, and to find out year by year how far they have been successful.

With regard to cooperation, just let me make one remark. There are two kinds of cooperation, and if we attempt to consider it scientifically we must not mix them up together. There is that form of cooperation in which the capitalist or employer pays the labourer—not altogether in wages, but by giving him a share of the profits. I was very hopeful that by such means the relations in question might be made better; and I am still hopeful, but perhaps not quite so much so as I was, because I see clearly two accompaniments of this. One is that we cannot, and must not, expect the labourer to take both sides of the bargain. We must not expect him to suffer loss, for sometimes there is loss. He cannot, if he is working from week to week, unless he has himself become a capitalist by saving, do without his daily and weekly wages. Therefore we have to pay him his share of the profits while we cannot make him responsible for a share of any loss. He cannot, then, be said to be a sharer in the profit and loss; he is only a sharer in the profit. Then, again, I think if this were generally done we should find that it would be merely a mode of payment, though perhaps a more satisfactory mode; but we might again have disputes as to the share of the profits he ought to have. This does not prevent us from watching these experiments with great care and anxiety, and with great hope. Then there is the other mode of cooperation, which may be called cooperation proper—that is to say, the cooperation in which labour is counted as capital, and the labourer becomes a shareholder, and, putting in some little savings also, is an actual sharer in the enterprise. Allusion has been made in our discussions to the growth of this kind of cooperation in this district. We know it very well in Bradford, and especially in the neighbouring towns. We have seen, for instance, the enormous and most satisfactory success of the Rochdale Cooperative Store. It is more difficult to apply this principle to production; but I am most anxious to see the experiments in that direction scientifically observed. I am told, though I do not know whether the statement is altogether borne out, that cooperative mills have been tried, and, to a great extent, have succeeded in Lancashire, and that cooperative mills, where established, passed the commercial crisis with great stability. Experiments of this kind are most interesting, and I can only say that I welcome them with great hopefulness. As an employer of labour (for I cannot forget that I am still an employer) I think there is great advantage in working men thus employing themselves and finding out the position of the capitalists, and also discovering that there is not always a profit, but sometimes a loss, and that we must not, when we look to men who have made large fortunes, altogether forget that fortunes have been lost. Again, though I cannot aspire to be a statesman, yet as a politician and as a member of the Government of the country, I hail the success of these experiments still more hopefully. It is said that one of the great causes of stability in America, and even in France, notwithstanding its many convulsions, is the large number of peasant proprietors; and I think we should have some share of the same kind of stability in this country by having a large number of working men with their own stake in the country and their own interest in its prosperous government. One or two facts have come out even in our discussion which have shown pretty clearly that it is not at all fair, nor true, to suppose that the wages of the working man are in all cases, or I may say even generally, so lavishly spent as some persons suppose. If we could only get a really dependable statistical statement of the increase in the savings of the working classes in one form or another in the last few years I believe we should be astonished and delighted. The success of benefit building societies (upon which we have had a paper in our Section) is only one instance illustrative of this fact. I feel, however, that I cannot leave this labour question (the condition of the labourer in England) without one further remark, and that is some allusion to the movement amongst the agricultural population. There, again, what a progress will,

after all, be acknowledged by any person however much opposed to the movement. The progress we have made is shown in Mr. Arch's meetings and Mr. Arch's speeches: what a progress compared with the rick-burning in the southern counties when I was a boy, some forty years ago! I cannot enter into the question now; but I confess I am not sorry that there is a movement amongst the agricultural population. I do not in the slightest degree, in making these remarks, blame their employers. I believe they have acted as other employers would have done, and in some cases better, for they have been brought more into contact with their people; but I do think the fact of it being supposed that no agricultural labourer could combine with his fellow labourers did do something towards making their wages lower than those of other classes of the community.

But in watching this movement I think we who, by our position, are not much interested in it, should watch it with very great sympathy for both sides. The condition of the agricultural labourer is in many cases that which ought to excite our sympathy; but the position of the farmer also is a very difficult one. His profit is not of that nature that he can make a large increase of money payment without a good deal of difficulty; and I therefore think it is a favourable feature in this movement that there is a third class somewhat connected with it (the landlords) who are in a position which enable them to act as moderators on both sides, and whose interests are to some extent involved in the matter. May I just throw out a hint to the Section, that I think it would be a very good thing if a paper could be produced before it really bringing the laws of political economy to the solution of this question—how far the rent that is paid for land affects the question of the wages of the agricultural labourer?

There are only two other remarks that I would make on this matter before I leave it, which concerns not so much the condition of England as what has happened outside of England, but which cannot but have an effect upon England; and, first, it is this, that if there was an attempt to describe progress in economical well-being for the last thirty or forty years, there would be one great fact which would be preeminent before all others—the abolition of slavery in the United States. I am not now entering into the moral evils of slavery; but it may not be out of place in me to allude to what would have been the consequences to economic science if the slave power of the South had succeeded, and in that great country, the United States, compulsory rather than free labour had been acknowledged to be the corner stone of the social system. I believe that historians will hereafter admit that the failure of that bold and well-planned attempt to seize hold of power in the United States in order to promote slavery was almost the greatest escape which civilization ever had. But however much we may rejoice over that escape, we must not forget that the spirit of slavery still exists. We hope we may have struck some blow against slavery this year on the East Coast of Africa; but I am made more sorrowful than hopeful from what I have seen of the matter during the last year or two. The efforts made by men of our own tongue, and, I fear, by men of our own race, to carry on what is practically a slave trade in the Pacific Islands, are most dispiriting, and demand our earnest endeavours to check them in every way we can. I will only just allude to the attempt which is being made in many western countries, in which there is a demand for labour, to forcibly import Chinese coolies wherever it is possible to do so. I have, however, some hope in regard to both these matters. I believe the moral sense of England has determined that her name shall not be shamed by the slave trade in the Pacific, and I hope we shall do our duty in regard to this Eastern traffic. I entertain this hope because the inhabitants of Eastern nations are becoming more and more able to take care of themselves.

This brings me to the other fact which, I think, we ought not to forget, and that is the remarkable intellectual movement which is now taking place among Eastern nations—a change which must result in great material advancement. I may allude to the wonderful reforms in Japan, which have so far appeared to have been carried out in real substance and with vitality of action, and which would seem to show that this country is waking up from the dead sleep of ages—a fact which will, I think, be hereafter acknowledged as the most extraordinary phenomenon of the last two or

three years. I think we also see something of the same tendency in China, and I shall be surprised if we do not see some similar movement in our own Indian possessions before long. Even the recent visit of the Shah of Persia (although there was much in it of not much reality) is, nevertheless, of itself a very interesting fact. It is a matter of some interest to us to find that the despotic ruler of an Eastern nation has thought it necessary to pay a visit to the West. It would be hard to foresee what will be the economic results of this intellectual movement, if it should go on increasing in extent and activity. It may cause to some extent competition with our labourers; but I believe that the general result of it will be that it will tend enormously to the advantage of both labour and capital.

Well, ladies and gentlemen, I have only one more remark to make before I sit down. There was one event (one sad event) that occurred last year to which I must allude. It would ill become me to close this address without making some reference to the irreparable loss which economic science has sustained in the death of Mr. Mill. That man, from whose lucid writings most of us have learnt what political economy we know, has been struck down in the full vigour of his thought, with his power of expression undiminished. I think there is no one who would dispute that vigour, or who would deny that in his remarkable faculty for the exposition and the illustration of a truth, John Stuart Mill was unrivalled in our time, and hardly excelled in any other. But his loss cannot be measured by that faculty of exposition. He was one of those who not merely explained and declared principles, but who endeavoured to apply them. He was not content with stating problems; he did not shrink from the attempt to solve them. I know that many of us would not in all cases accept his solutions; but who of us is there who would not acknowledge the perfect sincerity of his motive—the absolute truthfulness of his action? Many of you knew him well: I had not that privilege; but I knew him well enough to feel that the spirit with which, in attempting to apply his principles, he dealt with social and political questions, was so pure and noble, so sincere and single-minded, that he spread, as it were, an ennobling atmosphere around him, and for the time shamed away all mean intrigue and personal prejudice or vanity. I hope that those of us who in future try to study or to apply those principles will always keep before us the example of the author of 'The Principles of Political Economy.'

On the Use and Abuse of Peat. By Major-General Sir JAMES ALEXANDER, *C.B.*

The author described the waste of the valuable supply of peat in the county of Perth, in Scotland, by floating it down the river Forth in order to obtain the use of the clay subsoil for corn. The store of peat yet untouched was enormous, and the facilities for dealing with it were profitable. The peat in Shetland was said to be hard as coal, and the varieties of the Blairdrummond peat were described. The great consumption of coal was alluded to, and the danger of exhausting the supply, unless the export was checked by duty. The author next proceeded to describe the Falkland Islands peat, which was used for ships of war, and noticed the uses to which peat-charcoal was put for smelting iron. The method of working peat by peat-machine in Canada was shown by drawings, and a description given of the manner of working. The author referred to the stores of peat in France which were as yet unworked, and alluded to a peat-factory which had been forcibly closed in Ireland, but remarked that one was about to be erected at Dumfries.

On some of the Economical Aspects of Endowments of Education and Original Research. By C. E. APPLETON, *D.C.L.*

Endowments may be classified according to *source, object,* or *extent.*

Questions arising from the consideration of the *sources* of these are mainly extra-economical. Possible sources are private bequest, taxation, or a private bequest taken in hand and reapplied by the community.

The *object* of an endowment is always one of importance to the community, or believed to be so.

It is always an industry or employment. Institutions are only the means of industry.

The economical condition of the employment upon which endowment is spent may be:—(1) self-supporting, or capable of being made so; (2) partly or temporarily incapable of maintaining itself; or (3) wholly and permanently incapable.

Political economy does not necessarily involve non-interference with the law of supply and demand, but studies the effects both of interference and non-interference.

What then are the effects of the interference with the action of supply and demand involved in endowment in each of the three cases just mentioned?

1. Where the industry is self-supporting, or may be made so, it is to diminish the amount of production of the particular industry. This is the main ground upon which Adam Smith decides that the endowment of the higher education in universities is to be condemned.

Criticism of his views—question whether secondary and university education are or can be made self-supporting.

Endowment running to waste where it is unnecessary, affects also injuriously general production. Delicate economical calculations may arise out of this.

2. Instances of partly self-supporting industries are primary education and technical education.

Effect of partial endowment may be to stimulate production within the industry endowed; whereas without endowment it might fall to the ground altogether.

Primary education is a condition of public security, and therefore of a healthy economical state.

Technical education, like improved machinery, directly increases the capacities of producing wealth.

It is probable, therefore, that the return of the outlay in partial endowment of them will be greater than the diminution of wealth caused by the diversion from self-supporting industries of the endowment fund.

If primary or technical education ever became, by an alteration of the industrial state of the country, self-supporting, the continued endowment of them would then, as in the former case, involve a waste.

It may be questioned also whether the effect of the "ladder of endowment," by which persons are enabled to rise from lower to higher and the highest grades of education (however advantageous it may be politically to draw the *élite* of every class in the community up to the top), is economically advantageous; for it tends to draw off the best minds from particular industries, and thus to impair the power inherent in the latter of improving themselves. The soundest economical condition, it may be contended, is when the best minds are distributed throughout the community, and can act beneficially upon every form of production, instead of being centralized in a single class.

3. An industry is permanently incapable of supporting itself when the commodity which it produces is unsaleable. This is the case with original research in science.

Distinction of useful and liberal studies.

Mill's statement that the labour of the *savant* is a part of production, and its endowment a productive part of public expenditure, seems strictly to apply only to those researches which render inventions and improvements of the means of production or distribution possible.

Mr. George Gore's enumeration of these shows that they are mainly confined to researches in Physics and Chemistry.

The other physical sciences, such as Natural History, Botany, Ethnology, &c., and the study of letters, of language, or of history, however important in themselves, are not in the same sense industries which have any effect upon the increase of wealth-producing power.

They supply, it is true, the materials of education, which, as we have seen, is a remunerative industry; but science, of whatever kind, is essentially an end in itself, and therefore not in the majority of cases or necessarily a commodity, *i. e.* means to any thing else.

The idea of an end in itself does not fall properly within the science of political economy. A form of well-being, such as knowledge or culture *per se*, is one of the ends for which all commodities or utilities exist as means.

The inference that if we endow means we should *à fortiori* endow the ends for which those means exist, is a strictly valid one, but an inference not falling within the province of economical discussion. But the proposition from which it is an inference may be said to be taken from political economy.

The Poor-Law and its Effect on Thrift. By S. C. T. Bartley.

On Benefit Building Societies. By J. Arthur Binns.

These Societies are defined by the writer as agencies for the collection of money to be advanced upon real securities, and not for the purpose of building in their corporate capacity. There are "terminating" and "permanent" Societies, the former passing out of use, the latter growing continually in influence and usefulness. Terminating Societies labour under difficulties in equalizing the income and the outflow of their funds, from which the permanent Societies are free.

Members may join a permanent Society, or leave it, at any time. If an investor, a member may withdraw his money, with interest and profits; if a borrower, he may repay the amount he owes. In either case his connexion with the Society is determined by himself. There are differences in the mode of management, but not very important; and the "Bradford Third Equitable" may be taken as, upon the whole, a fair representative of these successful institutions.

This Society has 5800 members, who pay regular monthly contributions after the rate of 10*s*. per share, and who receive $4\frac{1}{2}$ per cent. and profits (usually 1 to $1\frac{1}{2}$ per cent. more) for their money. Ten shillings per month amounts, without profits, to £120 in 14 years and 3 months. The amount invested, or any part of it, may be withdrawn at any time on a month's notice, or the member may suspend his contributions, and permit his money to remain at interest. This saves fines, and often preserves money which enforced withdrawal would cause to be wasted. The fines in 1872, on an income exceeding half a million sterling, were only £94.

A second class of members (about 1400), who pay not less than £5 at once, pay when they please, and are not subject to fines at all. They receive interest and profits like the first class. Both are subject on withdrawal to a charge of one shilling for every £5 taken out. Out of the fund so raised the management expenses are paid.

A third set of investors are "loan" depositors. They have special facilities for withdrawal; they receive 4 per cent. interest without profits, and they are not charged with expenses of management.

The Society is managed by nine Directors, a Secretary, and a Treasurer. There are also Solicitor, Surveyors, Auditors, and Stewards. All contributors in the first and second classes vote in the election of these officers annually, and all are eligible for appointment. The loan-holders, who number about 7000, are not members, and do not vote.

The money collected is first used to meet withdrawals, and the remainder is advanced to borrowers on security of real property. More than £200,000 was so lent in 1872. At the end of that year, the total amount actually owing to the Society, and secured by 1642 mortgages, was £835,000. The total income in 1872 was £537,000, which was received in nearly a hundred thousand separate sums, and its separate payments for withdrawals and advances numbered 16,000.

The Bradford "Second Equitable" has 6277 members, and an income of £265,000. The "Leeds Permanent" and "Leeds Provincial" have together 17,280 members, and an income of £565,000; the "Halifax Permanent" has 6167 members, and receives annually £174,000. The whole of the Societies in England and Wales are probably 2500, and the total number of members 1,000,000. The Royal Commissioners on Building Societies describe them as "A group of bodies with a subscribed capital of over £9,000,000; a loan and deposit capital of over £6,000,000, over £17,000,000

total assets, having over £16,000,000 advanced on mortgage, and an income of over £11,000,000."

These Societies have grown spontaneously, rather in the absence than under the protection of legal enactments. It is the province of Parliament to consolidate into law the existing practice, which experience has tried and proved to be safe, instead of attempting to remodel it into something altogether different, foreign to the purpose for which the Societies have been instituted, and not adapted to meet the wants of their members.

Dwellings for the Industrial Classes. *By* WILLIAM BOTLY.

The author discussed sites, plans, and sanitary effects, &c. of cottages, also the pecuniary advantages of some extensive operations, deduced from observations in various localities and statistical returns, showing the great requirement and its easy accomplishment. He noticed and particularized many of the model cottages and villages in England and Wales, those of the Society of Arts and the Prince Consort's at the Exhibition in 1851, those of the Society for the Improvement of the Dwellings of the Working Classes, the various companies, amongst others that of Sir Sidney Waterlow and "The Artisans, Labourers, and General Dwellings Company," observing that the latter had propounded a scheme solving the problem long wished for, that of erecting artisans' and labourers' cottages on a plan and cost to remunerate the builder, without being oppressive in the amount exacted from the tenant. They do away with the evils of overcrowding, imperfect ventilation, bad drainage and construction—not only so, but they show that a profitable return is secured on the outlay. The author then gave full particulars, illustrated by drawings of plans, elevations, &c. Amongst other things, he makes the following almost imperative:—

1st. South aspect (as most healthy, and in illness contributing to earlier convalescence).

2nd. The offices to be in the rear.

3rd. No cottage to be allowed to be built less than 15 or 20 feet above any neighbouring watercourse or sea-side high tide.

4th. That each cottage should have an allotted space for a good vegetable garden, as the cottager growing his own vegetables will teach his children to weed, hoe, &c., and will not spend his hard-earned money at a beer-house.

On the Influence of Large Centres of Population on Intellectual Manifestation. *By* HYDE CLARKE.

After considering how far town populations are a means of exhausting those portions of the rural populations by which they are supplied, an examination was made of the towns, showing that there was a greater manifestation of intellectual vigour than in the country. This was assigned to two chief influences, one the extent of the population, and the other the continuous effect of educational institutions, as shown in collegiate and cathedral towns. Thus the establishment of large towns with adequate educational provision was treated as contributing to the national advancement. The gradual development of communities in prehistoric times and among the lower races was referred to as illustrative of the influence which the foundation of towns exercises in the history of civilization.

On Peat. *By* F. HAHN DANCHELL.

Statistics and Observations on the National Debt and our Disbursements from the Revolution in 1688 to the present time, showing the advisability of ascertaining our Annual Governmental Capital and Current Expenditure. *By* FRANK P. FELLOWS, *F.S.S.*

This paper gave statistics of our National Debt from the time of its commencement in 1691, when it was £3,130,000, the interest being £232,000, or about $7\frac{1}{2}$ per

cent.; that it rose to its highest point in 1815, when it was £861,039,000; that it was in 1868-69 £749,314,000, since which it has been reduced to between £720,000,000 and £730,000,000.

The given Income and Disbursement for Civil, Military, and Naval expenditure and interest on debt were, as given in Government Account:—1832 to 1837 about £50,000,000 yearly; 1839 to 1843 about £52,000,000 yearly; 1844 to 1854 about £57,000,000 yearly; 1855 to 1873 about £70,000,000 yearly. Since 1854 the Revenue Departments, which up to that time only paid into the Exchequer the net amounts earned, after paying therefrom salaries and expenses, have by Peel's Act paid the *whole* amount received to the Exchequer, thus swelling the stated income, and the salaries and expenses have been voted from the public purse. Hence about £6,000,000 must be added to the income and disbursements of years previous to 1854, or the figures must be raised in 1844 to 1854 from £57,000,000 to £63,000,000 in order to compare them fairly with the figures given since Peel's Act. Errors constantly arise from this not being known.

Unless, however, we know also (what we do not know and what it was the object of the paper to urge) the value of the property of the Government in land, buildings, shops, and stores, &c., how it has increased or decreased during this period, and how it stands year by year, these figures give no real information as to the state of our national assets and liability or of our national current expenditure; and the paper was read in continuation of other similar papers read before this Association and the Statistical Society of London with the view of urging that a Capital and a Current Account should be kept in each Government Department similar to that now being introduced at the Admiralty, so that we may know year by year what is the real expenditure of the Government both for investment or capital and also for current purposes, neither of which we know now.

The Savings-Bank in the School. By J. G. Fitch, *one of the Assistant Endowed Schools Commissioners, and Her Majesty's Inspector of Schools**.

This paper consisted mainly of some facts which the author had recently gleaned in the course of a visit to Belgium respecting the working of the "*Caisses d'épargne*" in the Communal Schools of Ghent. It appeared that without any Government influence, but merely through the energetic initiation of one of the professors in the University of Ghent, M. Laurent, aided by the schoolmasters and mistresses, the system of saving has been very efficiently introduced into the schools; so that five sixths of the children in attendance have savings-bank books (*livrets*) and bring their centimes regularly as they obtain them to the teachers, to be by them deposited, as soon as the saving amounts to a franc, in the public savings-bank at 3 per cent. interest. Ghent is a town of about three fourths of the population of Bradford; and in it the number of young people under instruction who are depositors has steadily risen in the course of seven years to 13,032. Statistics showing the gradual growth of the system, under the watchful care of the Communal School Council, the professors, and the elementary teachers, were given by the writer of the paper, from which it appeared that in the Free Primary Schools there are in all 7989 scholars (boys and girls), of whom 7583 have savings-bank accounts, the aggregate sum thus deposited amounting to 274,602 francs, or about £10,984. In the Infant Schools (*Ecoles gardiennes*) there are 3039 children, of whom 1920 have *livrets*, representing a sum saved of 66,523 francs or £2651. In those primary schools which are frequented by the better classes who pay for their instruction, there are 1079 scholars, 640 of whom have deposited in all the sum of 22,687 francs or £907; and in the schools for adults, which are partly held in the evening and partly on Sunday, there is a total number of 3285 men and women, of whom 2889 are depositors, and whose united deposits amount to 99,252 francs or £3970. Thus, through the agency of the scholars alone, a total sum of £18,512 has been saved, giving an average of rather more than 35 francs each to 13,032 depositors. Mr. Fitch argued earnestly that in England the increase of wages did not increase the

* A fuller account of this experiment is contained in an article, by the same author, in 'Macmillan's Magazine' for March 1874.

permanent prosperity of the working class if it merely gave to them more leisure and a greater number of immediate gratifications, nor unless it were realized in the form of better furniture, more books, a share in a building or cooperative store, or some form of provision for the future, which would increase the self-respect and dignity of the workman. Yet saving was a habit very difficult to acquire, especially by the recipient of weekly wages accustomed to live from hand to mouth. It could not be urged on the attention of workmen by employers without some suspicion of interested motives; it had never been strongly encouraged by the ministers of religion; it could not well be enforced by any Government authority; it might even be doubted whether any system of lecturing or theoretic instruction on economics, either in the school or in the workmen's institute, would ever be very efficacious. Economy was an act, a habit, to be learned mainly by practising it; and if learned at all, it should be learned early. The school was the right place in which to acquire this habit. Teachers and school managers were in an unusually favourable position for helping the poor in this way. They could without difficulty open the needful accounts with the Post-Office Savings Bank, and their motives were in no danger of being misunderstood by the parents. The child who foregoes an immediate indulgence, who saves his halfpence in order to procure a better equipment of books, clothes, or tools on leaving school, and who experiences the delight of finding interest begin to accrue when his saving amounts to a shilling, has learned a lesson in self-restraint and forethought which will abide with him for life. The paper concluded with the description of some of the details by which the introduction of the plan might be facilitated with the help of teachers, members of school boards, and others, and by the expression of a strong wish that the experiment so successfully made in Ghent might be studied and imitated in England.

On the East Morley and Bradford Savings-Bank. By THOMAS HAIG.

This savings-bank was opened in the year 1818. The town being then very small, its early progress was slow. It had reached its climax in May 1864, when 32,500 persons had deposited £1,273,363, including interest, and there remained in the bank £248,396 due to about 10,000 depositors. From that time to November 1869 the bank declined at the average rate of five to six thousand pounds a year, owing to the reduced rate of interest and the narrowed limits as to the amount of deposits; while depositors would readily avail themselves to any extent of other modes of investment at a higher rate of interest.

To stay its further decline and extend its usefulness no course seemed open but to adopt the suggestion of the Savings-Bank Act, and to open a department for the receipt of deposits for investment on other securities upon which a higher rate of interest could be paid. Accordingly, rules having been prepared, adopted, and certified, the new department was opened in April 1870 for the receipt of larger amounts on interest at 4 per cent. per annum, with power to withdraw twenty pounds without notice once in three months, and larger sums after notice proportioned to their amounts.

Up to the 13th September, 1873, 3257 accounts had been opened in this department, on which 10,736 deposits had been made, and 4001 withdrawals. The amount of deposits (with interest to April last) was £274,245 13*s*. 10*d*., and the withdrawals £65,559 7*s*., leaving £208,686 6*s*. 10*d*. due to 2763 depositors.

Of this sum £160,000 in various amounts had been invested with the Bradford Corporation for limited periods at 4½ per cent. per annum. Other sums had been advanced on mortgage of real property, under the direction of a Finance Committee, assisted by an eminent firm of solicitors and an experienced professional valuer.

The two departments are kept perfectly distinct, and together meet the requirements of the class of depositors whose benefit was contemplated by the Legislature in the Savings-Bank Acts.

On the Income-Tax Question. By T. G. P. HALLETT.

Educational Statistics of Bradford. *By* JAMES HANSON.

The object of this paper is to furnish a brief statistical account of the state of education in Bradford. The term education is employed to denote the ordinary agencies concerned in imparting knowledge and promoting culture in the earlier periods of life. After giving a brief history of the establishment of day schools in Bradford, the author considers the question of what number of children ought to be under instruction in Bradford. The Registrar-General estimates that in the middle of the present year the population of the borough would be 156,609. At 231 per 1000, between the ages of three and thirteen years, we shall have in the borough 36,170 children of school age. Deducting 10 per cent. for sickness and other causes, there remain 32,553 of school age, constituting the gross number that ought to be under instruction. What are the facts of the case? One seventh of the children between three and thirteen belong to the middle and upper classes. Taking one seventh from 32,553, we have 27,903 as the number of children of the poorer classes that require to be educated in schools where the fee is less than ninepence per week.

The number of children in the fifty public elementary schools which exist in Bradford are then given, the total on the books being 19,434. The number of children in the 65 private adventure schools was found to be, in 1871, 2866; and it is estimated that the number is the same at the present time. This gives a total number of children in schools where the weekly fee is less than 9*d.* as 22,300. It has been found on inquiry, however, that of the seventh part of the entire juvenile population belonging to the upper and middle classes, 4650 in number, only 2517 are provided for by middle-class schools, private tuition, &c.; and it may fairly be concluded that the balance, 2133, are educated in the public elementary schools. We must then add the 2133 to the number that require to be provided for in public elementary schools. The figures amended will then stand thus:—

Children between three and thirteen of the working class	27,903
Children sent to popular schools by well-to-do people	2,133
Total..................	30,036
Children actually in popular schools..........................	22,300
Left without day-school instruction..........................	7,736

It must especially be borne in mind that the figures we have hitherto been dealing with simply represent the children on the school-register. Nothing is told us about the character of the education that is being received by these 22,300 children; and yet this is a most vital point in attempting to ascertain the state of education in a community. With one exception the adventure-schools of this kind were in 1871 deemed inefficient by the Inspector of Returns, and were not taken into account at all in reckoning the school provision of the borough. As to the education given in the advanced schools, the author believes it to be equal to that of similar schools in any part of the kingdom; and in the last twenty years the standard of teaching in these schools has been very materially advanced. Coming to the education obtained in the popular elementary schools, we must take into consideration several circumstances. 1. In the first place, the difference between the numbers on the registers of the schools and the average attendance is very great. The numbers on the registers of the fifty schools are, as we have seen, 19,434, while the average attendance only amounts to 12,028. Here is an elimination of 7406 children at once. An able inspector, Mr. Fitch, has remarked that "it cannot be said of a school that it is, in any effective sense, educating a larger number than that represented by its average attendance." The Bradford schools, therefore, cannot be said to be really educating more than 12,028 children out of the 19,434 on the books. The others are irregular attenders, that gain little good from their casual visits. 2. The difference between the registers and the average attendance is rendered so large owing to the presence of a great number of half-timers in the Bradford schools. This feature must be deemed a hindrance to the effective education of the children of the working classes. There are in the schools of the borough about 6000 half-timers. The system can only be accepted as a boon

where parents and society are indifferent to the education of children, and would otherwise systematically neglect it. Its educational value has been overrated. Reporting on this district in 1870, Mr. School-Inspector Wilde justly remarks that its advantage is the regular attendance which it ensures where work is regular; but he observes:—"The disadvantage of the system is that parents, knowing their children will be obliged to attend school when they begin to work, do not send them while young, on the plea that when they go to the mill they will get their schooling." 3. The character of the education imparted in the elementary schools would be most clearly shown if we could know how long the children remain at school, and what progress they make in their studies. We want to know what proportion of the 12,028 are presented for examination, what they are examined in, what they know of each subject, and what is the mental culture effected. The author cannot give exact information on these points. The inspector for the district, Mr. Baily, has kindly supplied the following facts:—In the forty schools he inspected between September 1872 and March 1873 in Bradford the average attendance was 10,333; the number qualified for examination 7601; actually presented for examination 6319; number of passes, in reading 5092, in writing 5270, in arithmetic 3859, in one special subject 169, a second special subject 87. Thus out of the ten thousand in average attendance, only 3859 pass in arithmetic in all the standards. The inspector is unable to give the numbers in each standard. As a substitute for such specific information, it may assist us to an approximate conclusion if we assume that the Bradford elementary schools are equal to the average of such schools throughout the country. Applying to the statistics of the Bradford schools the proportions that we find exemplified in the last report of the department for the whole of the inspected schools of England and Wales, we should have the following results. Out of the average attendance in our fifty elementary schools of 12,028, there would be:—

Qualified for examination	8334
Actually presented for examination	7000
Presented in the first three standards, I. to III. or 82 per cent.	5698
Presented in the upper three standards, IV. to VI. or 18 per cent.	1243

That is, out of 19,434 on the registers, and 12,028 in average attendance, only 1243 would be presented in Standards IV., V., and VI., while 5698 are presented in the earlier standards. Further, as to those that would pass without failure in any subject. According to the same proportions, the Bradford schools would pass in Standards I. to III., 3528, and in Standards IV. to VI., 690; that is, out of 19,434 on the registers, and 12,028 in average attendance, only short of 700 would be instructed sufficiently to be able to pass without failure in the higher standards. Now, when we remember that the highest standard only requires in arithmetic a knowledge of proportion, fractions, and decimals, and a corresponding proficiency in reading and writing, these facts indubitably show what a miserable state our system of education is in. 4. In trying to form a judgment of the character of the education supplied in the public elementary schools in this town, there is one other feature of the general system that must just be mentioned, although its workings cannot be brought out here. The author refers to the inherent tendency of fostering mechanical teaching, mere *memoriter* knowledge and cramming, rather than the acquisition of accurate knowledge, the unfolding of the faculties, and the framing of these to right habits of thought. It would be interesting to know what is the cost of the agencies which achieve these meagre results. This cannot be given exactly. Out of the fifty elementary schools now in existence, thirty-eight gained Government grants last year; the rest are seeking for these grants. These thirty-eight schools got £6883 17*s*. 10*d*. from the Imperial fund last year, and for the operations of the year the fifty schools will obtain from £8000 to £9000 of the parliamentary vote. This large amount of public money is spent in Bradford on what are called "efficient" schools. No teachers, however competent, can secure a really good education without a regular, continuous attendance for a series of years on the part of the children. Our system fails because it wants the condition las

mentioned; its effects are not permanent; they are so meagre and superficial that, to a large extent, they are lost: they are evanescent and unfruitful; and on this account the system is exceedingly costly, without a commensurate return. If tested by economic principles, the system would be pronounced unsound and wasteful. In reference to school accommodation in Bradford, many of the schools would accommodate more than are in attendance. The present provision in the elementary schools is for 21,171 children. The eight schools that are being built by the School Board will accommodate 4800 more; so that there will be accommodation for 25,971 —say 26,000. It has been shown that there are 30,036 children requiring accommodation; but if we deduct 3000 for half-timers, we shall have 27,036 as the gross number of children who require accommodation, with a provision of 26,000. There is, however, accommodation for about 3000 in the private adventure schools. Passing now to evening schools and classes, there are a great number of night schools held in private houses and private schools, of which no statistics can be given. In the public institutions and elementary schools, a list of which is given, it was found that there were on the books last year 3027 students, with an average attendance of 1657. Art- and science-classes have greatly increased of late years through the encouragement extended by the Government. A detailed table of the statistics for last year of all the classes of both art and science in the borough, the subjects studied, the number under instruction, and the number examined, shows the following results:—That 595 persons were under instruction in art, and 465 of these were examined. In science 564 were under instruction, with 613 individual examinations. It thus appears that in the science and art classes together 1159 persons have been instructed. Another educational agency in extensive operation in Bradford is that of Sunday schools. From the statistics supplied in the paper, it appeared that there are on the books of all the Sunday schools in the borough 31,460 children and young persons, with an average attendance of about 21,000. Statistics as to the Public Libraries of the town were given, and show that in the libraries of the Mechanics' Institute, Church Institute, Female Educational Institute, and the Free Library, there are 32,225 volumes, with issues last year amounting to 156,000. And then we must not forget the interesting fact that almost every one of the eighty-six Sunday schools has a library for the use of the children and teachers; and these contain altogether about 47,000 volumes.

On Postal Reform. *By* W. Hastings.

On Railways Amalgamated in Competing Groups. *By* B. Haughton, *C.E., F.S.S.*

The author said that the railways of England had now settled down into something like a complete and efficient system, suitable for the necessities of the country. Their cost had been something like £600,000,000, and the period of time occupied in their construction had been, dating from the commencement of the construction of the Liverpool and Manchester Railway (1826), forty-seven years. The trunk lines were finished, and the question arose, What next? The answer was natural; let them arrange and control and manipulate this vast machinery so as to produce symmetry and order out of the seemingly chaotic mass, and so as to extract a maximum of effective work out of the minimum of efforts. This was the problem which the English people had now taken in hand. He believed that the railway traffic of the country was conducted as perfectly as it could be, considering the extent of our experience, the nature of the instruments we were obliged to use, and the patchwork character of the general railway reticulation. One of the methods proposed as a panacea for the existing unsatisfactory condition of affairs was that of a surrender of the railways into the hands of the State. Assuming that State management must follow State purchase, the advantages claimed by its advocates might be stated as follows:—(1) Unification and symmetry; (2) economy of working; (3) elimination of Parliamentary charges; (4) immunity from accidents; (5) reduction of rates and fares; (6) increase of

accommodation, especially in the matter of improved train correspondence; (7) adoption and adaptation of all the latest inventions; (8) the necessity of the operation lest the railway companies might become the dominant power in the State. The objections to State management usually urged were:—(1) Centralization; (2) communistic tendency of the act; (3) patronage; (4) the possibility that the State might get a bad bargain, as other inventions might arise more economical and convenient than the present means of locomotion; (5) the enormous cost of the undertaking; (6) the necessity to buy up the canals, coasting, steam, and sailing vessels competing with the railways, the docks and harbours owned by the railways, locomotive factories, coach and waggon factories, the coal- and other mines used by the railways. With reference to the economy of working under State control, the author regarded it as extremely problematical. The number of journeys made in 1871 in the United Kingdom was 375,000,000 exclusive of those made by season-ticket holders, of whom there were 188,392; and he estimated that the total number of journeys made in the year was 409,000,000. During the same period one passenger only was killed for each 13,630,000 journeys made; and assuming that each passenger made seventy-five journeys per annum, and that he was endowed with the faculty to renew his life at pleasure, he could only be killed once in 181,733 years of travelling. And supposing that the wounded by railway collisions were to be killed in the ratio of ten to one, a passenger could only be wounded once in 18,000 years. These and other figures proved that there was practically no danger for the railway traveller either of being killed or wounded in a railway collision. It was to the nearly superhuman efforts of railway officials, high and low, as well as to the inventive genius of the engineer, that the passenger owed his comparative safety; and he might feel assured that State management would not diminish the present death-rate. Having reviewed the objections usually raised against the *status quo,* the author considered those generally made against adopting the opposite horn of the dilemma, viz. Government management. Centralization of control had some advantages, but they were not such as to neutralize its shortcomings. It was because he was convinced that it was beyond the intellectual capacity of this country as in this epoch limited, to manage a network of railways 13,000 miles in extent on the principle of unification under State control and in accordance with the present wants, that he advocated a system of railway groups as against a Government or centralized management. It was clear that the State could not enter into a carrying competition with independent companies. The objections to expropriation on the ground of patronage required no further notice than this, that the companies employed about 250,000 persons, the nomination of whom to their several offices would bring with it doubtless the possession of their suffrages. It was questionable if the railway property could be bought for less than a thousand millions, if even it could be done at that figure. Truly the friends of expropriation must be endowed with a romantic boldness of enterprise, and a faith that would remove mountains. The scheme he had to place before the Association started upon the principle that it was the duty of the Government to govern, and not to trade; and it adopted, as a foregone conclusion, that the State ought not, and could not if it would, buy and manage the railways. The intention of the scheme was that the existing railways, owned at present by 106 different companies, should be amalgamated into four competitive groups, to be owned and managed by four great companies, taking their shape and direction from the people of the island, and having a due regard to the *terrain* as well as to the importance of the chief centres of trade and manufacturing towns, cities, mines, docks, ports, harbours, and so forth, as well as to the status of each principal railway company. He suggested that the four amalgamated groups should preserve the titles of four of the existing companies:—(1) the London and North-Western group; (2) the Great Western group; (3) the Great Northern group; (4) the Midland group. Neutral territories, except in a very few instances, had no place in the scheme, as being contrary to its principles, those of competition pure and simple. The London and North-Western group would absorb the London and North-Western, Lancashire and Yorkshire, Cambrian, Mid Wales, Caledonian, Great North of Scotland, South Stafford, London, Brighton, and South Coast, and

some of the smaller networks to South Wales, Shrewsbury, and Hereford (jointly), and the Cheshire lines (jointly). The Great Western group he would compose of the Great Western, South-Western, Shrewsbury and Hereford (jointly), Cheshire lines (jointly), South-Eastern and some of the smaller lines in South Wales. The Great Northern group would combine the Great Northern, Great Eastern, North-Eastern, North British, and the Highland (jointly). The Midland group would consist of the Midland, Manchester, Sheffield, and Lincolnshire, Glasgow and South-Western Highland (jointly), Brecon and Merthyr, Bristol and Exeter, and London, Chatham, and Dover. The four systems might in the fulness of time become practically four distinct railway networks, each one visiting the most important commercial centres of the kingdom, and each independent, or nearly so, of the others. When the systems had attained such a condition, it might be said that the absolute perfection of the scheme had arrived: that was to say, a choice of four different routes would be offered to any person travelling from one place of importance to any other place of importance. The author proceeded to enumerate the advantages of the system he had thus sketched out.

Commercial Panics. *By* W. D. Henderson.

The writer considered the whole question of banking on the "historic method," and showed how it was that various laws had from time to time checked the natural development of the business of banking. He then pointed out that of all trades banking was the one which ought to be freest, as it dealt not with commodities, but with the representatives of commodities and the credit of individuals. After pointing out how it had happened that in England the capital of the banks was small in proportion to their liabilities, and the specie also small, and that the Bank of England held the entire specie reserves of the country, he proceeded to point out that the remedy for the small capital was now in the hands of individuals, who could either singly or in combination, or in the latter case, under either the Limited Liability Act or the unlimited, form what banks they pleased. As regards augmenting the specie reserves he showed that this also was largely in the power of the banks, and that what was required was chiefly that the London banks should form a fund of specie to which each would require to contribute, and settle their clearing-house transactions, not by cheques on the Bank of England, but by cheques on this fund. He showed how the possession of this fund would steady the action of the banks in times of pressure, and that it would be open to the banks, if a great emergency arose, to hand its amount, which would probably be 4,000,000, to the Bank of England. He then considered the one exception to the general principle of free trade, and admitted that the issue of small notes was really a monopoly, as the holders of these notes were involuntary creditors. The assumption of the Act of 1844 was examined, viz. that a circulation of notes should fluctuate as one of gold would do; and it was shown that this was impossible, and that in Scotland, for example, between May and July, there was a variation in the circulation of 16 per cent. from what the small note circulation might be expected to be on this theory, and what it actually was. He advocated the issue of these notes by the State, provided that the State held a large reserve of specie to secure their controvertibility. The amount of sovereigns in circulation was now about £75,000,000, and probably notes issued by the State would take their place to the extent of £50,000,000. Of this sum one half might be kept in gold and the other half in consols; and of course, as no interest would be payable on consols, the State would make a profit yearly of 3 per cent. on £25,000,000, or £750,000 a year. The writer then pointed out that in times of panic a portion of this gold might be rendered available. On the principle of the Bank Act of 1844, if the normal circulation was £50,000,000, it was inconceivable that it should ever fall below £30,000,000; and the First Lord of the Treasury and the Chancellor of the Exchequer might have power to sell, say, £1,500,000 of gold, and purchase consols for every 1 per cent. that the Bank rate rose above 8 per cent. There would thus be a margin of £5,000,000 from the small note department, viz. the difference between £25,000,000 ordinarily held of consols and the £30,000,000

which might be held, and in addition £4,000,000 from the London Clearing House available to allay a panic, and this without any loss to the country, which would indeed have £21,000,000 of gold to export. The writer then repeated his view that, except small notes, there should be complete freedom in banking, taking reasonable precautions to prevent fraud, and pointing out that it would be well to allow all new banks, or banks not now circulating, to issue notes of £20 and upwards, as their notes circulated among the wealthier classes, who were quite able to take care of themselves. He believed that with freedom in banking the banks would be larger and with larger capital, and safer than at present, and that extreme mercantile convulsions could be avoided, although, of course, pressures arising from men's imprudence might always be expected *.

On the Shoddy Trade. *By* SAMUEL JUBB.

The shoddy manufacture was commenced at Batley, Yorkshire, in the year 1813, being introduced by Mr. Benjamin Law, of the same place. The produce thereof are heavy woollen cloths chiefly, and they are used for coatings and other purposes. The essential raw materials used in the fabrication of shoddy cloths are shoddy and mungo, in combination with wool and noils.

Shoddy is produced from soft rags, such as cast-off stockings, flannels, carpets, &c.; and mungo from hard rags, such as worn-out dress-coats, tailors' cuttings, disused fine tablecloths, &c. Both these kinds of rags, which formerly were nearly valueless, are torn or ground up by a machine, the principal feature of which is a cylinder set with sharp iron teeth, and which revolves at a rapid rate; this machine is known locally by the name of "devil." The effect is, that the rags are converted into a kind of wool or flock, and hence capable of being mixed with sheep's wool.

The supplies of rags are drawn partly from the large cities and towns of the United Kingdom, and also from various foreign countries. London is the principal market. Shoddy and mungo, viz. the rags in the prepared state, are largely imported from the continent of Europe.

Shoddy varies from 1*d.* to 1*s.* per lb., mungo from 1½*d.* to 20*d.* per lb., according to quality, colour, staple, &c. The wool used together with shoddy varies from 6*d.* per lb. to 18*d.* per lb., and with mungo from 1*s.* to 2*s.* 6*d.* or 3*s.* per lb.

There is a large quantity of fine Australian wool consumed in the shoddy manufacture.

Shoddy cloths vary from about 1*s.* 2*d.* to 12*s.* per yard, 54 inches wide, and always appear cheap, whilst as a fact they are an economical fabric, and as such extensively patronized by the working and poorer classes at home; at the same time a large export trade is done in them to our colonies and the principal markets of the world.

Shoddy cloths are of course scribbled and carded, spun, woven, milled, raised, dyed, and finished much in the same way as cloths made of all sheep's wool.

The shoddy manufacture has its centre at Batley and the adjoining borough of Dewsbury, where large mills are in operation, employing thousands of workpeople. Batley is the principal seat of the trade, and at this time (1873) contains from fifty to sixty mills engaged in this business.

A considerable number of other places in the district, and at a distance, are more or less occupied in the heavy woollen manufacture, which have radiated from Batley as from a common centre. There are no statistics showing the extent of the trade in the aggregate, though it is desirable there were; it may, however, be stated that there are without doubt 3000 power-looms used in this trade at Batley. Speaking of power-looms (that is to say looms driven by steam-power, in contradistinction to hand-looms, which were worked manually) they (power-looms) have

* It is a little curious that remedies almost identical with what is suggested here were adopted a day or two afterwards in New York. The banks there ceased to conduct their exchanges against legal tender, and the Government bought lands; and in each case the amounts were similar to what is here indicated, viz. £4,000,000 and £5,000,000 respectively.

been used on a large and increasing scale for some twenty years back; females are chiefly engaged in tending power-looms, intermixed with a few young and adult men. Female labour has been in great demand in the heavy woollen district since the introduction of power-looms; and the result is that this kind of labour now receives about twice the remuneration it formerly did. Men's wages, though advanced, have not progressed in any thing like a corresponding ratio; females who are proficient at the power-loom can earn in full employ eighteen shillings per week. The employment in the woollen manufacture is, generally speaking, healthy; the oil, which is put upon the wool before scribbling, keeps down any dust, and is wholesome to the operative.

In conclusion, the trade seems destined to expand in future years as it has done in the past, and to become, large as it is, much larger still. In its first initiation, and for some time afterwards, the trade was not without detractors; but it has outlived all opposition, and has become firmly established as one of the leading manufactures of the kingdom.

Confederated Homes and Cooperative Housekeeping. *By* Mrs. E. M. King *.

In a short introduction the writer showed that the proverbial attachment of Englishmen to their homes was not so deep as was supposed; neither were the comforts of home extended to all members of society. Men in easy circumstances frequented clubs, ladies left home for balls and parties; men in a poorer class resorted to public-houses, institutes, &c.: the women, when they could, went out for a little gossip. The large number of single men and women living in boarding-houses and lodgings proved that home was to them little more than a name.

One well-known cause of the discomfort of home was the want of good servants. Some considered the mistresses to blame for them, some the servants; the happy-medium people said both were to blame; while she (Mrs. King) considered that neither were to blame, but thought that the position in which mistress and servant were placed with regard to one another caused this discomfort, producing discontent on the part of the servants, and the assumption of responsibility by mistresses as to the life and conduct of their servants, which they could only carry out by depriving the servants of nearly all liberty and free enjoyment of life.

The discontent of servants was owing to the state of semislavery in which they were kept. Mrs. King urged that servants should be placed in the altered condition of free workers; and in order to effect this, the home of the employer should no longer be the home of the employed—that is, that servants should no longer *live* in our houses. In order to effect this change, our system of living in isolated homes must be given up, and one of cooperative housekeeping be substituted; and instead of one set of servants working all day and, as occurred often, far into the night, relays of servants should come for a certain number of hours and be replaced by others.

Mrs. King called attention to the want of proper schools of cookery, and declared that the attempt to teach it by lectures or showing how to make a few dishes must prove a failure, the art and science of cookery being a branch of technical instruction requiring study and constant practice.

With regard to the mechanical arrangements of the homes, the best machinery for economizing labour should be made use of; but it would be better not to attempt to obtain luxuries, the most perfect organization for the supply of the necessaries of domestic life being one of the greatest luxuries—these mechanical arrangements being for heating, lighting, water-supply, and waste-pipes (speaking-tubes, ventilation), and "lifts."

As water should be carried into all rooms where required, so should all waste matter be conveyed out of rooms by a turn of the hand of the occupier of the room. Domestic service was made degrading by giving women degrading work to perform, and so effectually preventing women of higher class entering into it.

Mrs. King advocated the education of boys and girls together, and affirmed that in a home on the plan she recommended a school could be attached in

* Published *in extenso* in the 'Contemporary Review' for December 1873.

which the system of "mixed education" could be best tried, as the parents could then daily watch the effect it had upon the character and behaviour of their children.

In conclusion, Mrs. King said, "The plan of home, domestic and social, life I have endeavoured in this paper to explain is a wide one, one which, if carried out, would result in many wide reforms—in the emancipation of a class, in organizing the whole range of female domestic labour, in founding schools for technical education in the newly organized profession, in producing tenfold more order, ease, and comfort in home-life, in reducing the cost of living, in opening a field of honourable employment to women of all classes, in offering the best means for the care and education of children, and, lastly, showing a remedy leading to the greater purity and elevation of our social intercourse. And however I may have failed in working out the details of my plan, it is one well worth our earnest consideration and attention."

On the Effect of the Increase of Prices of certain Necessaries of Life on the Cost of Living, and its Relation to the Rates of Wages and Salaries. By Professor LEONE LEVI.

On the Economic Use of Endowments. By J. M. D. MEIKLEJOHN, *M.A.*

On Capital and Labour. By W. MORRIS.

On the Bradford Building Trades. By ARCHIBALD NEILL.

The building-stone trade of Bradford and district is considerable in extent, there being about 6000 men engaged in stone-getting and dressing in the quarries in the locality. The produce is about 450,000 tons per annum, and something like £650,000 in value. The men have no trades' union, but have as short hours as, and are better paid than, the workmen employed in the building-trade who have trades' unions. They have seldom much difficulty in obtaining an advance of wages or other requests, as they are guided by the state of the trade. When they see a good demand for the stone they understand that to be their opportunity, and each set of workmen asks their employer or master for an advance of wages, shorter hours of labour, or other advantages; and they have so timed their applications that the quarry masters have found it possible to comply with them, and that without injury to the trade; for although these men have shorter hours and are better paid than any other men similarly employed in any part of this country, yet the stone found in this district, being highly appreciated and much used, the trade has improved notwithstanding the repeated advances made to the workmen. As a large proportion of the stone (fully one half) is sent off by rail or water to London, Manchester, Liverpool, Birmingham, and other places equally distant from Bradford, the increase of wages to the workmen in this trade is all to the advantage of the Bradford district, and will be so until the high wages modify or destroy the demand for the stone. The stone in this neighbourhood is of the sandstone order, but of various qualities. There is the ordinary coarse sandstone, known to engineers as the Bramley Fall, and the white beds of Calverley, and the finer qualities of ashlar, such as Cliff Wood, Bolton Wood, Wrose Hill, and Idle, of which most of our large warehouses are built. When these stones are used in buildings set on their natural bed, they will last for ages. The delfstone or fine riving sandstone is also found in great abundance, in layers from 1 inch to 30 inches in thickness, and in large posts or slabs. These can be split into a variety of thicknesses, according to the natural vents or beds of the stone. When split in this way the bed is true, and flags, landings, steps, or other flat stones are obtained with little labour; and if worked while fresh, the labour is easily executed; but when dry, it becomes hard and difficult to work with hammer and chisel. A great number of the men employed

at the quarries are engaged in working as masons, preparing flags, steps, sills, landings, and a variety of masons' work. These men work mostly by piece or contract, and earn from 30*s*. to £3 per week. The stone so prepared, except a portion of the flags and landings, is all sent out of Bradford, as the Bradford Building Trades' Union masons object to stone so dressed being used in this district.

There is little machinery at work in the stone trade of this district as yet; for although stone-dressing and moulding-machines have been at work on the Bath, Portland, and other soft stones in the southern counties, they are not adapted to work the hard stone of this district. Little progress has been made in dressing Bradford stone by machinery, the great grinding-power of the stone on any tool being a considerable difficulty. Low speed can only be used, and the result is slow progress with the work. Yet something is done in this way, and at half the cost of hand-labour. [The author has constructed a dressing-machine for cutting and squaring stone, and also a rubbing-machine for dressing quoins and plane surfaces; a full description of these machines was given to the Mechanical Section of this Association.] At present few masters have introduced machinery into their workshops; and at present not more than 10 per cent. of this class of work is done by machinery. The small amount of scaffolding used by builders in Bradford is a peculiarity, and must attract the attention of strangers. Our large mills and warehouses are raised without the aid of the forest of poles or heavy timbers to be seen in other large towns. There are about 1400 building masons in Bradford. They are nearly all in the union. They have 7¾*d*. per hour, and work 49½ hours per week. They discourage overtime; and it is very seldom resorted to, it being felt in Bradford, both by master builders and men, that 49½ hours is sufficient labour for any week, and not more than nine hours in any one day. There are about 1000 carpenters and joiners, machine-joiners, and steam-sawyers in Bradford. One half are in trades' unions; and, so far as the author can form an opinion, the better class of workmen in this case are unionists; and he has never known the union interfere except for good. Their wages are 7½*d*. per hour, time and overtime, as in the case of masons. They have always welcomed the use of machinery, and made the best of it. Much good machinery has been introduced into this trade; and Bradford is not behind any town in the country for the quality and variety of the machinery in use, some being as yet in exclusive use here. All the heavy work in carpentry (roof-framing, floors, dovetailing of beams, joists, &c.), as well as all the heavy work in joinery, is done by machinery in a first-class manner, making the labour of the joiner easy, care and skill being more in request than hard work. The machinery in this trade executes fully 60 per cent. of the labour in preparing carpenters' and joiners' work (the fixing, of course, having still to be done by hand-labour)—the result being that although wages have risen in this trade upwards of 60 per cent. during the last twenty years, yet the price of finished work, exclusive of fixing, is not more than it was before that time. We have 200 plasterers in Bradford. They are nearly all in the union. They are paid 7¼*d*. per hour, and work 50½ hours per week. There are about 200 plumbers and glaziers and 50 slaters, with hours and pay similar to those of the joiners. There are 750 masons' labourers, all in the union. They are paid 6*d*. per hour, and work 49½ hours per week. There are about 1300 men engaged as excavators, carpenters' labourers, and assisting the other trades; and, with the exception of 120 plasterers' labourers, they are not in the union; but the average wages will be about the same as the union labourers, and their hours of labour the same as those of the respective trades with which they are connected. There are about 400 painters, paid 6½*d*. per hour; grainers and ornamental writers from 7*d*. to 9*d*. per hour. They work 52½ hours per week, and overtime as required. There are 300 smiths and mechanics directly connected with the building and stone trade. They have the same hours as the joiners and masons, and receive 7*d*. per hour. About one half are in the union. There is little clay for hand brick-making in this district, it being largely mixed with stone and shale. Machinery has had to be resorted to for grinding, either in the dry or plastic state. After being ground in a plastic state, it is sometimes moulded by hand, sometimes by machinery; but when ground dry, of course it is always moulded or compressed into brick by machinery. There are about 600 men and lads engaged in this trade, their working hours being the same as masons.

The lads have 2½*d.* per hour, the men 5½*d.*, and some are paid by the piece, and make on the average 8*d.* per hour. All the bricks are burned in Hoffman's, Morand's, Baker's, or other permanently built kilns. These kilns do not emit smoke, and are therefore well adapted for burning bricks in towns. They also economize coal, the saving compared with the manner of burning bricks before their introduction here being equal to 300 per cent. in value. Still bricks are 30 per cent. dearer than they were twenty years ago, arising out of the expensive plant, higher rate of coal and wages, and the greater care taken in their manufacture, the bricks being of a superior quality than formerly. Although stone is largely in use in this district, even for the commonest purposes, yet the number of bricks used and the amount of capital employed is a hundred times greater than twenty years ago. The author estimates that the turnover in the trades for the erection of buildings in Bradford only amounts to about £850,000 per annum. There is considerable capital invested in the trade; and Bradford builders have a fair reputation for good work, and frequently extend their operations to places at a great distance, the woodwork being almost all made here, and in some instances the stone has been dressed and fitted for large buildings sixty miles away.

The want of well-instructed men as masters, foremen, and leading men being strongly felt in the trade, induced the master builders of Bradford in 1869 to establish a trade technical evening school for the young men engaged in the business. The object of the school is to instruct the men in a scientific knowledge of their trade; but it has been found necessary to have classes for reading, writing, and arithmetic, as numbers of the apprentices have been neglected in their elementary education, and it is hard to teach technical science to those who read with difficulty, and whose knowledge of arithmetic is uncertain. There are four teachers in the school, three of whom hold Government certificates: and we have during the past year put them under Government inspection, so that we obtain payment on results. We have had in all £28 from that source. But we are in an unfortunate position with our technical education. The class of instruction given and required seems not to have been understood by the Science and Art Department; and up to now they have ignored the most important knowledge, that knowledge which will enable a workman correctly, scientifically, and in the best manner to obtain the true lines from which he can with confidence produce the most complicated piece of work, such as wreaths, twists, curves, and other forms required in staircases, handrails, and masonry; the intersections and forms of mouldings having different angles; the manner of obtaining the length of angle-rafters, and the lines for cutting the same: the cut and lengths of purlins against angle-rafters, especially where the rafters and purlins are moulded; a true system of developing circles in all their varieties; the true lines for the formation of each stone in a circular upon circular arch: every stone in this form of arch has an irregular side, all requiring very careful formation, and which can only be obtained by a true development of geometric lines; this is also the case with skew arches when properly executed, and when built in large ashlar. There is much information of this description needed by a first-class workman, and it is, so far as the author knows, a knowledge peculiarly their own. It has not been taught in schools. Architects, as a class, know very little of it; it is workmen's lore: it has been left to them, and some 10 per cent. of workmen have a fair knowledge of such subjects; yet few, if any, are what 90 per cent. might be if such schools as the Bradford Builders' Technical Schools existed throughout the country. The Government Examiners for Certificates in Building Construction, so far as can be perceived, are unacquainted with the existence of this peculiar scientific workmen's geometry: and it would be well if they were to take counsel with men who are practically engaged in our technical schools—men who not only theorize, but go into actual practice in the school. We have followed theories in our school with actual construction. If our pupils are studying the skew bridge, circular upon circular arch, wreaths of wood or stone, roof construction, or such like, the bridge or arch is constructed as a practical illustration of the geometric principle or theory. Technical schools can never have efficient help from Government until this technical knowledge is better understood by the Science and Art Department. Architectural

drawing is well understood, and we find that provision is made for successful students in it; but in this difficult, and to workmen more important branch of scientific technical drawing there is no help whatever. The author states that from the opening of the school an average of fifty young men have attended the classes four nights a week from seven to nine o'clock. The charge is from 3*s.* to 5*s.* per quarter. The majority of the masters pay for their apprentices. The schools can accommodate a much larger number than attend, yet the results are good. Young men are being properly educated for managers, foremen, or first-class workmen. It will be found that a good training in the school will fit a man for good employment. A youth so instructed will be a better citizen as well as a better workman. Some say if you educate men they will not work. This is so if they are educated *not* to work. If it is impressed on a lad in his training that he is to have an education to save him from working he will not work; but if, on the other hand, he is brought up with the idea that he must have an education when a boy that it may enable him to work when a man, to work with intelligence and skill, then it will be found that he is more industrious than he who received little or no education. Those who fear that educated workmen will not work are very frequently the same men who cry out against the shortening of the hours of labour, and hold out the increasing competition with Germany and German workmen as a reason why we should continue the long hours and increase our industry in every possible manner so that we may preserve our country's trade and commerce. Do they forget that these strong competitors are all educated, and far above what we in this country are likely to be for years to come? Is it not our want of education we have to fear?

The author concluded his paper with observations on the influence of trades' unions on the building trades.

On the Relation of the Banking Reserve of the Bank of England to the Current Rate of Interest. By* R. H. Inglis Palgrave, *F.S.S.*

This paper gives a complete analysis of the returns respecting the Bank of England in the Appendix of the Report from the Select Committee of the House of Commons on the Bank Act of 1857, and the one published this year, containing a similar statement, continued to the close of 1872. By following out this analysis, it becomes clear that the average rate of discount charged by the Bank of England depends in general terms on the proportion borne by the reserve of the Bank to the liabilities. Between 1844 and 1872 the average deposits of the Bank have risen from £13,000,000 to £28,000,000, the banking reserve from £8,000,000 to £12,000,000, the balance of London bankers from £900,000 to £7,000,000, the average of bills discounted from £4,000,000 to £6,000,000, temporary advances from £1,000,000 to £3,000,000, and the note circulation from £20,000,000 to £25,000,000.

It will be observed that the proportion borne by the reserve to the liabilities had diminished since 1844 from 58 per cent. at the earlier to 42 per cent. at the later date. Meanwhile the proportion borne by the balances of the London bankers to the banking reserve of the Bank of England, which was 10 per cent. in 1844, had increased to 62 per cent. in 1872; and the minimum rate of interest, which averaged for the years 1844–56 £3 15*s.* 3*d.*, increased on the average for 1857–72 to £4 3*s* The details of the proportion of the reserve to the liabilities at each change in the rate of discount for the years 1844–72 were given in Tables; and these show that it is the proportion of the reserve of the Bank, the immediate supply of money, which governs the current rate of interest. This furnishes a remarkable and exact instance of the working of the law of demand and supply. The amount of money generally in the country has greatly increased. The amount of banking deposits has also largely increased. The amount of banking reserve has not increased in a like proportion; and it is the amount of the supply immediately available which governs the price of the commodity required.

* Published *in extenso* in the 'Journal of the Statistical Society,' Dec. 1873; and als separately by E. Stanford, London.

On Purity and Impurity in the Use and Abuse of Water. *By* Major-General MILLINGTON SYNGE, *R.E., F.S.A., F.R.G.S., F.R.L.*1

Opinion of a Turkish lady on western habits in the use of water. The contrast presented by Turkish to western habits of obedience to religious injunctions in respect to cleanliness of person. The systematic corruption of rivers would be impossible consistently with eastern habits in the use of water. Western nations, even when they use water for personal ablution, reclothe themselves in uncleansed garments: their houses are externally filthy and often so internally. The use of water for assuaging thirst an instinct rather than an act of reason. Analogy between sobriety and cleanliness. On the indirect effects on social life of habits of cleanliness, on the wage-taking classes and on the capitalist. On the progress of the age and the direction of that progress: its dealings with water. On sewer-pollution. On the difference between the clean and the unclean. On the science of purification. The effects on air, water, and earth of contact with man. The elements of the ancients. Fire. On "waste," the meaning in which the term is employed. The art of purification. Purification not attained by dilution of the impure, which is only spreading impurity: it can be attained only by transmutation, the ceaseless miracle of creation. The contrast between transmutation and water-carriage of refuse, which sets all the laws of transmutation at defiance: it multiplies the volume of waste and causes dangerous evils, and destroys the value of a natural fertilizer. The cost of "main-drainage" of London. The purification of water. The standard of purity is a restoration to normal condition. The consequences of adopting the standard in remedying water-pollution: its easy application. The difficulties caused by sewage-corruption of water increased by the volume employed. Reclamation or restoration to the normal state should take place within the limits of the locality which causes the defilement. On the power of intangible proportions. The easiness of water-pollution; but its dire consequences. The properties of charcoal. The deodorant and disinfectant powers latent in impurity discovered by Mr. Stanford: it is the restoration of the impure to the condition of the pure.

MECHANICAL SCIENCE.

Address by W. H. BARLOW, *Esq., C.E., F.R.S., President of the Section.*

IT appears to have become an established custom that the Presidents of the several Sections of the British Association should say a few words by way of address prior to opening the proceedings of the Meeting; and while I feel that I should neglect a duty if I did not comply with this usage, yet I know that I shall have need of all your indulgence and support while I endeavour to fulfil it.

I should have felt some difficulty in the selection of a subject were it not that the genius *loci* naturally suggests some subject connected with manufactures.

It has been remarked by an eminent writer that there is no single circumstance which distinguishes our country so remarkably from all others, as the vast extent to which we have carried our contrivances of tools and machines for forming all those articles and conveniences of which so large a quantity is consumed by almost every class of the community. And I think it would be difficult to select a locality where the results of thought and study, the achievements of genius, and the effects of strong good sense and long practice in the mechanical arts are more plainly shown than they are in the place where we are now met and in the surrounding district.

It is, however, not alone in tools and machinery that this country has attained a high position; it stands preeminent also in the utilization of waste or incidental products, and in the production of new materials.

In the observations which I have to address to you I shall not attempt a general

survey of a subject so vast and so varied as the manufactures of this country, nor shall I attempt to describe the many new and beautiful inventions and mechanical appliances which form a distinguishing feature of the age in which we live; but I shall endeavour to draw your attention to one of the new materials, namely *modern steel*—a material which, though of comparatively recent origin, has already become an important industry, and whose influence in the future seems destined to vie in importance with that resulting from the introduction of iron.

I have used the term "modern steel," because, although the great movement in simplifying and cheapening the process of producing steel is necessarily associated with the name of Mr. Bessemer, yet we have further important steps taken in a forward direction as to the production and treatment of steel by Dr. Siemens and Sir Joseph Whitworth and others, both in this country and abroad.

It is now seventeen years since Mr. Bessemer read a paper at the Meeting of the British Association at Cheltenham, which was entitled "On the Manufacture of Iron and Steel without Fuel."

Not long afterwards I attended one of the early experiments made by Mr. Bessemer in London. On that occasion most of those who were favoured with an invitation to be present saw for the first time that wonderful process in which, by the simple aid of a blast of atmospheric air and the addition of a little manganese, a caldron of melted cast iron was, in the space of some twenty minutes, converted into a material which approached wrought iron in so far as it was malleable, but differed from it in other ways, the precise character and quality of the material produced being at that time not fully known.

I was kindly permitted by Mr. Bessemer to take away with me one of the small ingots cast on that occasion, and had it made into a bar in the workshops of the Midland Railway at Derby with the object of testing its strength.

Just as the bar was finished it broke under the hammer, and an attempt to weld it together again, treating the metal as iron, failed. This led to a consultation among the smiths who had assembled round this mysterious bar, and after some further trials the metal was unanimously pronounced to be *steel*.

Among those who attended that experiment at Mr. Bessemer's works, there were not wanting some of that class who, though they admitted the genius and intelligence which devised the process, and expressed their admiration of it as a scientific curiosity, were nevertheless very incredulous as to its ever becoming practically useful; and it was not without much labour and skill in surmounting the difficulties of the case, indomitable perseverance in overcoming rooted prejudices, and great courage in undertaking the necessary expenditure, that Mr. Bessemer succeeded in producing that most valuable new material now known as "Bessemer steel."

It is satisfactory to know that Mr. Bessemer has often expressed his firm conviction that had it not been for the publicity given to his invention through the paper which he read before the Mechanical Section of the British Association in 1856, and the great moral support afforded him by men of science whose attention was thereby directed to it, he believes that he would not have succeeded in overcoming the strong opposition with which his invention was met in other quarters.

About this time, or perhaps a little later, a material was produced called "puddled steel," and about the same time the metal known as "homogeneous iron."

The movement which had begun in the production of cheap steel was further assisted and developed by the regenerative furnace of Dr. Siemens, by the introduction of the Siemens-Martin process of making steel, and further and most important progress is suggested by the recent process introduced by Dr. Siemens in making steel direct from the ore.

According to the returns published by the Jury of the International Exhibition of 1851, the total annual produce of steel in Great Britain at that time was 50,000 tons. At the present time there are more than 500,000 tons made by the Bessemer process alone, added to which Messrs. Siemens's works at Landore produce 200,000 tons, besides further quantities which are made by his process at Messrs. Vickers, Messrs. Cammells, the Dowlais, and other works.

I shall not, however, detain you by attempting to trace up the history and progress of steel, nor attempt to notice the various steps by which this branch of

industry has been brought to its present important position. My object is to draw attention to this material as to its use and application for *structural and engineering* purposes.

The steel produced by the Bessemer process was at a very early stage employed in rails and wheel-tires. In both these applications the object sought was endurance to resist the effects of wear, and toughness to prevent fracture by blows. There does not exist at present sufficient information to determine accurately the relative values of steel and iron when used for these purposes. As used for wheel-tires, steel had to compete with iron of the highest quality, but it is nevertheless introduced on most of our railways. The iron used in rails was not of such high quality, and the difference in duration shows a very marked advantage in the employment of steel, the duration of steel rails being variously estimated at from three to six times that of iron.

Steel is also extensively used for ships' plates, and by the War Department for lining the interior of the heaviest guns; while Sir Joseph Whitworth and Messrs. Krupp make guns entirely of steel, though for these purposes the metal is of different quality and differently treated, in order to withstand the enormous concussions to which it is subjected.

And, further, we have steel used in railway-axles, crank-axles for engines, in boilers, in piston-rods, in carriage-springs, and for many other purposes.

But, notwithstanding these various employments of steel, there has been, and there continues to be, a difficulty in applying it to engineering structures in this country.

The want of knowledge of the physical properties of steel having been the subject of remark at a discussion at the Institution of Civil Engineers in 1868, a Committee (composed of Mr. Fowler, Mr. Scott Russell, Captain Galton, Mr. Berkley, and myself) undertook to conduct a series of experiments upon this subject. Our services were of course rendered gratuitously; but the expenses of carrying out this inquiry, and the samples of steel to be tested, were liberally furnished by the firms of Messrs. Bessemer, Messrs. Jno. Brown & Co., the Barrow Hæmatite Company, the Bolton Iron Company, Messrs. Cammell & Co., Messrs. Lloyds, Fosters & Co., the Newark Bridge Company, Messrs. Naylor, Vickers & Co., Messrs. Turton & Sons, Messrs. Firth & Sons, and Messrs. Siemens.

The experiments recorded consist of four series.

The first were made for the Committee by Mr. Kirkaldy with his testing-machine in London, and were chiefly directed to ascertain the relation which subsists between the resistances of tension, compression, torsion, and transverse strain.

In this series of experiments twenty-nine bars, 15 feet long, were used, each bar being cut into lengths, and turned or planed into suitable forms for the respective tests, so that a portion of each bar was subjected to each of the above-mentioned tests.

The tensile resistance varied in the different qualities of steel from twenty-eight to forty-eight tons per inch, and the experiments established conclusively that the relation subsisting between the several resistances of tension, compression, and transverse strain is throughout practically the same as in wrought iron; that is to say, that a bar of steel whose tensile strength is 50 per cent. above that of wrought iron will exhibit about the same relative increase of resistance under the other tests.

They further showed that the limit of elasticity in steel is, like that of wrought iron, rather more than half its ultimate resistance. The total elongation under tensile strain, and the evidences of malleability and toughness, will be referred to hereafter.

The second series recorded in the book published by the Committee gave the results of tempering steel in oil and water. They were made by the officers of the gun-factory at the Royal Arsenal at Woolwich, and show a remarkable increase of strength obtained by this process. This property of steel is now fully recognized and made use of in the steel which forms the lining of the largest guns.

The third series of experiments was made by the Committee upon bars 14 feet long, $1\frac{1}{2}$ inch in diameter, with the skin upon the metal as it came from the rolls.

The object of these experiments was specially directed to ascertain the *modulus of elasticity*. They were made with the testing-machine at H.M. Dockyard at Woolwich, which machine was placed at our disposal by the Admiralty. The bars were obtained, with some exceptions, in sets of six from each maker, three bars of each set being used in tension and three in compression.

Bars of iron of like dimensions were also tested in the same way, in order to obtain the relative effects in steel and iron. In these experiments sixty-seven steel bars were tested whose tensile strength varied from thirty-two to fifty-three tons per inch, and twenty-four iron bars varying from twenty-two to twenty-nine tons per inch.

The amount of the extensions and compressions were ascertained by *direct measurement*, verniers being for this purpose attached to the bar itself, 10 feet apart, so that the readings gave the absolute extensions and compressions of this length of the bar.

These experiments, which were very accurately made, showed that the extension and compression of steel per ton per inch was a little less than wrought iron, that the extension and compression were very nearly equal to each other, and that the modulus of elasticity of steel may be taken at 30,000,000, which result agrees with the conclusions arrived at by American engineers on this subject.

This property of the metal is important in two respects. First, because inasmuch as the extension per ton per inch is practically equal to the compression, it follows that the neutral axis of a structure of steel, strained transversely, will be in the centre of gravity of its section, and that the proper proportion to give to the upper and lower flanges of a girder, when made of the same quality of steel throughout, will be the same as in wrought iron. Secondly, because the modulus of elasticity of steel is practically equal to that of wrought iron, and the limit of elasticity is greater, it follows that in a girder of the same proportions as wrought iron, and strained with an equal proportion of its ultimate tensile strength, the deflection will be greater in the steel than in the iron girder, in the ratio of the strength of the metals; so that if it is necessary to make a steel girder for a given span deflect under its load the same amount as an iron girder of the same span, the steel girder must be made of greater depth.

The fourth series of experiments were made by the Committee on riveted steel, and show clearly that the same rules which apply to the riveting of iron apply equally to steel; that is to say, that the total shearing area of the rivets must be the same, or rather must not be less, than the sectional area of the bar riveted.

Having thus obtained a knowledge of the behaviour of steel under different strains, we may trace in what manner its employment would operate on the weight of metal required for large engineering structures. But before doing so I would call your attention to the question of the absolute tensile strength.

Taking Mr. Kirkaldy's experiments in conjunction with those made by the Committee, there is a great range of strength exhibited, commencing as low as that of the best iron, and extending to about fifty-three tons per inch.

This great range of strength is due to the different qualities and make of the steels tested, and must not be mistaken for irregularity of strength in the manufacture; on the contrary, in the experiments made by the Committee, in which three bars of each make were broken, the strengths, with the exception of one set, are as uniform as in the iron bars similarly tested.

It is also to be observed that in applying steel to engineering structures we may dismiss from consideration those superior qualities which are of high price and made in comparatively small quantities. I propose therefore to confine my observations to the mild steels, such as are made by the "Bessemer," the "Siemens-Martin," and other processes, having a tensile strength varying from thirty-three to thirty-six tons per inch, a material which is made in large quantities and at moderate cost.

Following the same rule as is adopted for wrought iron (namely, that the maximum strain on the metal shall not exceed one fourth of the breaking weight), we may consider steel of this quality capable of bearing at least eight tons per inch, instead of the five tons per inch estimated for like purposes in iron.

We know from established mechanical laws that the limiting spans of structures

vary directly as the strength of the material employed in their construction when the proportion of depth to span and all other circumstances remain the same. We know also that, taking an ordinary form of open wrought-iron detached girder (as, for example, when the depth is one fourteenth of the span), the limiting span in iron, with a strain of five tons to the inch upon the metal, is about 600 feet; and it follows that a steel girder of like proportions, capable of bearing eight tons to the inch, would have theoretically a limiting span of 960 feet.

This theoretical limiting span of 960 feet would, however, be reduced by some practical considerations connected with the minimum thickness of metal employed in certain parts, and it would, in effect, become about 900 feet for a girder of the before-mentioned construction and proportions.

The knowledge of the limiting span of a structure, as has been explained elsewhere, enables us to estimate very quickly, and with close approximation to the truth, the weight of girders required to carry given loads over given spans; and although the limiting spans vary with every form of structure, we can obtain an idea of the effect of introducing steel by the relative weights of steel and iron required in girders of the kind above mentioned.

Assuming a load, in addition to the weight of the girder, of one ton to the foot, the relative weights under these conditions would be as follows:—

Span.	Weight of steel girder.	Weight of iron girder.
	tons.	tons.
200	57	100
300	150	300
400	320	800

Again, taking such a case as that of the Menai Bridge, which consists of two spans of 500 feet over the navigable waterway.

This structure is composed of four wrought-iron tubular girders, each weighing about 1500 tons, or 6000 tons in all; and in order to avoid the difficulties of scaffolding, each of these tubes was built on the shore, floated off on pontoons, and lifted bodily into its place by hydraulic machinery.

This great work was erected when the application of wrought iron to engineering works was in its infancy, and when wrought iron was the only available material for such a purpose.

With such materials only at command, and in the then state of knowledge of structures, the accomplishment of this bridge, capable as it is of carrying railway trains across clear spans of 500 feet, was an achievement far in advance of the time in which it was done, and worthy of the name of its great designer, Robert Stephenson.

But if this work had to be constructed now, and were made an open girder of steel instead of plate iron, the weight of metal required would be little more than one third of that used, and the cost of erection, the time required for its execution, and the total cost of its construction would be most materially reduced.

It is not alone in the relative weight or in the relative cost that the advantage of the stronger material is important, but with steel we shall be enabled to cross openings which are absolutely impracticable in iron.

It will naturally be asked why it is that steel is not used in these structures, if such manifest advantages would result from its employment.

The reason is twofold:—

1st. There is a want of confidence as to the reliability of steel in regard to its toughness and its power to resist fracture from sudden strain.

2nd. Steel is produced of various qualities, and we do not possess the means, without elaborate testing, of knowing whether the article presented to us is of the required quality for structural purposes. A third reason, arising probably out of those before mentioned, is found in the fact that in the regulations of the Board of Trade relative to railway structures, although rules are given for the employment of cast iron and wrought iron, steel has not, up to the present time been recognized or provided for.

Now, as regards the question of toughness and malleability, and referring again to Mr. Kirkaldy's experiments, it appears that in the tests of "Bessemer steel" eighteen samples were tried under tensile strain, the length of the samples being in round numbers 50 inches, and the diameter 1·382 inch; and that when these were subjected to ultimate strain, the elongation at the moment of fracture was in the most brittle example $2\frac{3}{4}$ inches, but generally varied from $4\frac{1}{2}$ to $9\frac{1}{2}$ inches.

In the experiments on transverse strain, in which the bars were nearly 2 inches square and only 20 inches between the points of support, all the "Bessemer steel" samples, except two, bent 6 inches without any crack. Again, in the experiments made by the Committee on bars 14 feet long and $1\frac{1}{2}$ inch in diameter, out of twenty bars of the milder quality of steel, sixteen extended more than 8 inches, and of these ten extended more than 12 inches.

As another example of the malleability of steel, I may mention that I have seen a piece of rail, weighing 80 lbs. per yard, and 12 feet in length, held by one end and twisted at the other, until it made $6\frac{3}{4}$ complete revolutions before it broke. The fracture occurred at one end, leaving about 11 feet of the rail in the twisted form which had been given to it.

In this twisted state the rail was laid on two bearings 3 feet 6 inches apart, and subjected to the blow of 1 ton weight falling 30 feet, and it bore one of these blows without breaking.

I have also used a considerable quantity of steel rails, the test to which they were subjected being 1 ton falling 20 feet on a 3-feet 6-inch bearing, and out of the whole number tested there was not one which broke with this test. The effect of the blow was to produce a set of about $2\frac{1}{2}$ inches; and if the rail was then reversed and struck on the other side, it became nearly straight again. As a rule, the rails yielded to the third blow; but I have seen seven blows given without producing fracture.

On the other hand, five of the bars tested by the Committee were of inferior malleability.

We have also instances in which steel rails break with the jar produced by being thrown off the waggons on to the ballast; and there is no doubt of the fact that steel is made and sold which is cold-short, and not reliable for use for engineering purposes. This irregularity appears to arise mainly from the difference in the chemical constituents of the metal or ores employed, or in the process pursued by different makers.

Another element of uncertainty appears to be that, in these modern and rapidly made steels, the precise time allotted to the several stages of the process, the degree of heat employed, and a variety of other circumstances have to be carefully observed, and any inaccuracy in carrying out the required conditions affects the quality of steel produced.

Nevertheless it is known that in the Bessemer process, if ores or metal of suitable chemical qualities are used and the process of manipulation is properly performed, the quality of metal produced is certain and regular in its results.

In the processes of Dr. Siemens there is not the same necessity for purity in the ore or metal required, the nature of the process being, I believe, such as to eliminate some of the ingredients which would prevent toughness being obtained, while tests may be made during the process of manipulation so as to ascertain that the metal is of the quality sought before it is run off into the ingot-mould.

Where large castings and metal of great solidity are required, as in making large guns, there is the method pursued by Sir J. Whitworth, whereby the metal is intensely compressed while in a fluid state.

The pressure employed is 20 tons per inch, and its effect in producing solidification is such as to shorten the ingot about $1\frac{1}{2}$ inch for every foot of length.

The treatment by compression is especially important where metal is required in large masses and of great ductility, because the larger the mass and the greater the ductility, the larger and more numerous are the air-cells, and the effect of the pressure is to completely close these cells and render the metal perfectly solid.

By this process mild steel can be made with a strength of 40 tons to the inch, having a degree of ductility equal to that of the best iron.

The more highly carbonized qualities, whose strengths range from 48 up to 72

tons per inch, show a decrease of ductility somewhat in the same ratio as the strength increases.

Without going into the numerous achievements of Sir Joseph Whitworth resulting from the employment of steel, in connexion with the extreme accuracy of workmanship produced at his works, or doing more than mention the flat-ended steel shot and shell which pass through iron plates when fired obliquely or penetrate ships' sides below the level of the water, I would call attention to those applications of steel which bear upon its strength and toughness.

In the first place, there are small arms made entirely of steel, of wonderful range and accuracy, capable of penetrating 34 half-inch planks, which is about three times the penetrating power of the Enfield rifle.

Secondly, there are the large guns, also entirely of steel, throwing projectiles from 250 lbs. to 310 lbs. in weight, and burning from 40 to 50 lbs. of powder at a charge, with which a range of nearly $6\frac{1}{2}$ miles is obtained.

In both these cases the degree of strength and toughness required in the metal is much greater than is necessary for engineering structures.

It is unnecessary to occupy more time in multiplying examples of the toughness of steel. It is well known to manufacturers, and must also be well known to many others here present, that steel of the strength of 33 or 36 tons per inch can be made, and is made in large quantities, at moderate price, possessing all the toughness and malleability required in engineering structures.

I will proceed, therefore, to the second part of the subject—namely, the want of means of knowing that a given sample of steel is of the quality suited for structural purposes.

With most other metals chemical analysis is in itself a complete and sufficient test of quality, but in steel it is not so. The toughness of steel may be altered by sudden cooling; and although the effect of this operation, and generally the effects of tempering, are greater when the quantity of carbon is considerable, yet it acts more or less in the mild qualities of steel; so that we cannot rely entirely on the aid of the chemist, but must fall back on mechanical tests. And in point of fact, seeing that the qualities required are mechanical, it is no more than reasonable that the test should be mechanical; for this includes not only the test of material but of workmanship.

Now there are two descriptions of mechanical testing, which may be distinguished as destructive and non-destructive—the one being beyond and the other within the elastic limit of the material. The destructive test is that usually applied to a part of an article manufactured, as, for example, a piece cut off a boiler-plate and tested by absolute rupture, or by bending or otherwise, whereby the strength and quality of the material in the plate is known.

The non-destructive test is that usually applied to the finished work, as in the test of a boiler by hydraulic pressure, or the testing of a gun by the proof-charge. The strain in this case is made greater than that which will arise in the daily use of the article, but is not so greatly in excess as to be beyond the elastic limit of the material.

As regards engineering structures, this second test is easy of application; but it affords no sufficient criterion that the metal possesses that degree of toughness necessary to resist the action of sudden strains.

It may be said that engineers may ascertain for themselves, by inspection and testing at the works, that they are being supplied with the material that they require; but assuming that the tests and mode of testing were in all respects satisfactory to them, and that the metal supplied was of the right quality, we have still to comply with the conditions prescribed by the Act for the Regulation of Railways, and we must satisfy the Government Inspector.

It is not to be supposed that he can attend all the required tests at the works; and the question remains, How is the Inspecting Officer of the Board of Trade to be enabled to distinguish the quality of metal in a finished bridge, when he is called upon to give a certificate that it is safe for public traffic?

If we could adduce clear and distinct evidence that the metal used for a bridge was of a quality which would bear 8 tons to the inch with as much safety as common iron can bear 5 tons, there can be no reasonable doubt that the Board of

Trade would make suitable provision in its regulations for the employment of such material.

The difficulty lies in the want of something whereby the quality of the metal may be known and relied upon with confidence by others besides those who made the article.

In gold and silver this is accomplished by the stamp put upon them, in guns and small arms we have the proof-mark, but in iron and steel we have nothing whereby the one quality of metal can be distinguished from another; and until some sufficient means be devised for this purpose, it is difficult to see how we are to escape from the position in which we are now placed—namely, that while we possess a material by which we can increase considerably the spans and diminish the weight and cost of engineering works, we are restricted to make designs and construct our works by a rule made for wrought iron, and adapted to the lowest quality of that material.

As the rule made by the Board of Trade in respect of wrought-iron railway structures may not be generally known, I here give it:—

"In a wrought-iron bridge, the greatest load which can be brought upon it, added "to the weight of the superstructure, should not produce a greater strain on any "part of the material than five tons per inch."

It will be observed that this 5 tons per inch is the governing element, irrespective entirely of the quality of metal used; and it is obvious that a rule so framed must act as a discouragement to any endeavour to improve the quality of metal, while it tends to induce the employment of the cheapest and most inferior descriptions which can be made under the name of wrought iron.

In endeavouring to seek an amendment of the rules, which will permit of the employment of steel or other metal of higher strength than 5 tons to the inch, I feel bound to say that I do not consider that the Board of Trade is alone responsible for the position in which the question now stands; and, as regards the Government Inspecting Officers, I can only say that in the numerous transactions I have had with them, and although differences of opinion have occasionally arisen, yet, considering the responsibility which rests upon them, I have found them anxious to afford all reasonable facilities so far as their instructions permitted.

The first step to be taken is to put our testing on a systematic and satisfactory basis.

The second is to establish some means whereby metal which has been tested can have its quality indicated upon it in such manner that it can be practically relied upon.

The experiments before referred to establish, sufficiently for all practical purposes, that the relation or proportion between the resistances to tension, compression, torsion, and transverse strain is about the same in steel as in wrought iron.

The testing required is therefore reduced to that necessary for ascertaining two properties only, namely the strength and the toughness or ductility.

The strength may be readily ascertained, and no difficulty arises on that head.

The whole question turns upon the test for ductility, or the resistance to fracture by blows or sudden strain; and it must be admitted that the tests employed for this purpose are not framed on any regular or satisfactory basis.

I may mention as an example the test of rails by a falling weight.

In the first place, as usually applied, it is made a destructive test, the weight and fall being such as to bend and render the rail unfit for use, however good its quality may be.

Secondly, being a destructive test, it is applied only to 1 or 2 per cent. of the quantity; and if this amount bear the test, the remainder are assumed to be like them. I have recently had occasion to know, in a case which came before me respecting iron rails, that this assumption may be entirely fallacious.

Again, we find 10 to 18 cwt. falling 5 feet used for iron rails, while 1 ton falling 20 feet and sometimes 30 feet is specified for steel, and yet both descriptions of rail are called upon to perform the same work when laid down in the road.

I believe the falling weight, or, in other words, the test by impact, to be a good and searching test for detecting brittleness; and it has the advantage of being cheap, quick, and easy of application, but it is questionable if it is applied in the best manner.

Except in cases of accident, when an engine or train leaves the line, rails of the weight now used in permanent way are never known to be bent by the passage of trains, but brittle rails will break.

The weight on the driving-wheel of a large engine is about 8 tons; the amount of vertical fall in passing along the line is necessarily very small; and we know by experience that this large weight with this small fall is sufficient to break inferior rails, while it leaves the good ones unbent and uninjured.

What we require of the test by impact is that it should be so arranged as to do what the engines do, detect the brittle rails without destroying the good ones; whereas, as now applied, it destroys the 1 or 2 per cent. of the rails submitted to the test, however good they may be, while it gives no information whatever regarding the remaining 98 or 99 per cent. of the quantity.

Another test for toughness or ductility which is very useful is the extension of the metal beyond the limit of elasticity.

In testing his fluid-compressed steel, Sir Joseph Whitworth employs this test upon a piece of the metal 6 inches in length. For a length of 2 inches at each end a screw is cut for the purpose of enabling the hydraulic apparatus to bring the strain to bear on the sample. The remaining 2 inches between the screwed portions is accurately turned down until the sectional area is exactly $\frac{1}{2}$ an inch.

The sample is now subjected to strain, and the recorded extension occasioned by the strain at the moment of rupture is treated as percentage or proportion of the 2 inches between the screws, and is described as the *percentage of ductility*.

But it is obvious the measure of ductility so obtained has reference to the particular length and dimensions of the specimen, and would be altogether varied if a long bar were tested instead of a short one.

There is, however, another evidence of ductility which, within certain limits, is independent of length—that is, the diminution of sectional area which takes place at the point of rupture; and the ratio which the original sectional area of the bar bears to the sectional area of the fractured end appears to afford a more definite measure of ductility.

Thus in the experiments of Mr. Kirkaldy, previously referred to, it appears that in bars 50 inches long and 1·382 inch diameter, the sectional area of the fractured end was in some cases less than five tenths of the original section.

In the bars broken by the Committee, which were 14 feet long and $1\frac{1}{2}$ inch in diameter, it was in the best samples under six tenths, while the best qualities of wrought iron similarly treated showed a ratio of about five tenths.

It is to be observed that such a degree of ductility as is presented by these samples is not needed in engineering structures, the wrought iron frequently used, and I may say generally used, for these purposes being of much less ductility.

Without, however, attempting to say what description of test may be found the best for ascertaining the property of ductility, it may be observed that what is required for this test is a definite basis to act upon, and that the samples should be so made as to render the test cheap, expeditious, and easy of application.

The next requirement is that when a piece of metal has been tested, and its qualities of strength and toughness ascertained, there should be some means of denoting its quality in an authentic manner.

To a certain extent this is already done in iron by the mark of the maker; but something more than this is necessary to fulfil the required conditions in steel.

What is termed steel, is iron with a small proportion of carbon in it. These two ingredients are necessary to constitute steel; and there may or may not be present in very small quantities graphite, silicon, manganese, sulphur, and phosphorus.

In connexion with the experiments made by the Committee, 14 of the samples were tested by Mr. E. Richards, of the Barrow Steel Works, 5 of which were kindly repeated by Dr. Odling.

Although there are some discrepancies in the results which we cannot account for, yet some of the characteristics are brought out clearly.

It appears that manganese may be present to the extent of four tenths per cent. without injury either to the strength or ductility, but sulphur and phosphorus, except in extremely small quantities, are fatal to ductility.

In the samples tried by the Committee and Mr. Kirkaldy, the quantity of carbon

varied from $\frac{1}{3}$ per cent. to nearly 1 per cent.; yet with this small variation in the carbon the strength ranged from 33 tons to nearly 53 tons per inch; and the ductility, represented by the ratio which the fractured area bore to the original section of the bar, varied from five tenths in the tough qualities, until in the harder samples there was no diminution perceptible.

All these materials are called steel, and have the same external appearance; but possessing, as they do, such a range of strength and such a variation in ductility, it becomes absolutely essential that there should be some classification or means of knowing the respective qualities among them.

The want of such classification casts an air of uncertainty over the whole question of steel, and impedes its application. To this want of knowledge is to be ascribed the circumstance that many professional men regard the material as altogether unreliable; while large consumers of steel, in consequence of the uncertainty of the quality they buy in the market, seek to establish works on their own premises and make their own steel.

This step has already been taken by one of the large railway companies, and is, as I am informed, contemplated by one of the principal constructive departments of the Government.

My attention has been recently and forcibly directed to the importance of steel through having been called upon, in conjunction with Mr. Bidder, Sir John Hawkshaw, Mr. Harrison, and Dr. Pole, to report upon the magnificent work designed by Mr. Bouch for crossing the Firth of Forth. This great work consists of a stiffened suspension bridge in two spans, each of 1600 feet between the supports.

To construct this work in iron, with a working strain of 5 tons to the inch, would involve such weights of material and magnitude of strain as to render it virtually impracticable; but in tough steel, capable of bearing 8 tons per inch, it is praticable to accomplish it and even larger spans.

Mr. Bouch has designed the chains of this bridge to be made of steel; and in addition to the honour which must attach to his name as the originator of this great and important work, he is further entitled to the merit of being the first engineer to break through the restrictions which confine our engineering structures to wrought iron, and to brave the difficulties which surround the employment of steel for railway works in this country.

I ought, I know, to apologize for detaining you so long on this one question of steel, but I consider that the difficulties under which it is placed are affecting interests of considerable importance.

Not only is a large and useful field for the employment of steel practically closed, but the progress of improvement in engineering structures is impeded both in this country and in other parts of the world where English engineers are engaged.

For in consequence of the impediments to its employment in England, very few English engineers turn their attention to the use of steel. They are accustomed to make their designs for iron, and when engaged in works abroad where the Board of Trade rules do not apply, they continue for the most part to send out the old-fashioned ponderous girders of common iron, in cases where the freight and difficulties of carriage make it extremely desirable that structures of less weight and more easy of transport should be employed.

In conclusion, and while thanking you for the patience with which you have heard me on this subject, I would observe that we possess in steel a material which has been proved, by the numerous uses to which it is applied, to be of great capability and value; we know that it is used for structural purposes in other countries, as, for example, in the Illinois and St. Louis Bridge in America, a bridge of three arches, each 500 feet span; yet in this country, where "modern steel" has originated and has been brought to its present state of perfection, we are obstructed by some deficiency in our own arrangements, and by the absence of suitable regulations by the Board of Trade, from making use of it in engineering works.

And I have considered it right to draw your attention to the position in which this question stands, well knowing that I could not address any body of gentlemen

more capable of improving and systematizing our methods of testing, or better able to devise effectual means for removing the impediments to the use of steel, than are to be found in the scientific and practical men who form the Mechanical Section of the British Association.

On the Lisbon Steam Tramways, 1873. *By* W. H. Barlow, *Jun.*

This paper was a description of the Lisbon steam tramways. The peculiarity of their construction is, that the permanent way consists of only one central rail, on which double-flange bogie-wheels, supporting the weight of the train, run. On each side of this central rail are longitudinal timbers, 9 inches broad, on which run the side wheels of the engine and carriages, said side wheels having no flanges. The driving-wheels of the engine are 14 inches broad, giving great adhesion in running on the timbers.

This construction possesses great facilities for ascending steep gradients and going round sharp curves. The ruling gradient was 1 in 20; the curves principally in use are from $\frac{3}{4}$ to 2 chains radius.

The author of the paper had travelled on the tramway at Lisbon, constructed as above, at a pace of twelve miles an hour, and in some places had travelled twenty to thirty miles an hour, and could therefore testify to its efficiency, while its economy spoke for itself.

The carriages are further balanced on the central bogie-wheels, so that they run like a bicycle; when running fast the side wheels are scarcely used.

The author remarked on the want of a construction of this nature for localities where the traffic would not justify the outlay necessary for constructing an ordinary railway; and, further, that it was a good construction to lay down, *pro tem.*, to develop the resources of a district, and gradually to be superseded by a regular railway. In France and in Portugal it is used as a tramway and laid along the public roads, and has been found to answer admirably.

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*On the Manufacture of Cards for Spinning Purposes**. *By* Daniel Bateman.

On the Saint-Gotthard Tunnel. *By* C. Bergeron.

On the Hydrostatic Log†. *By* Rev. E. L. Berthon.

On Huggett's System of Manufacturing Horse-nails. *By* F. J. Bramwell, *C.E., F.R.S.*

The author, in the commencement of his paper, remarks upon the fact that while for many years past ordinary nails have been made by machinery, and in more recent times even the screws which are used by carpenters (commonly called "wood screws") have been so made, the horse-nail has remained in the domain of handicraft, although its simple form and appearance would lead to the belief that it was at least as fit a subject to be the product of mechanical skill as is the carpenter's nail, and far more fit a subject than the carpenter's screw, requiring, as this latter does, a number of delicate and complicated processes, all of which processes, however, are now most successfully performed by a succession of automatic machines.

The author then shows that the horse-nail, notwithstanding its apparently simple character, has a speciality in its use which demands in it special qualities and involves a special manufacture.

The speciality in its use is that, unlike the carpenter's nail and screw, which are employed to penetrate mere inert and dead matter, the horse-nail has to be driven

* Published *in extenso* in the 'Engineer' for Oct. 3 1873. † Ibid.

into something alive; further, that while the nail must be so tough that it can be with certainty bent over at the point to "clinch" it when in the hoof, it must still be sufficiently stiff to penetrate the horny substance of that hoof, and to penetrate without risk of wandering from the true direction, as were it to do so it would be very likely to pass into the interior of the hoof and to lame the horse; and, as a final peculiarity, that the horse-nail when driven in is not there once and for all, but in the course of a few weeks it has to be withdrawn, and that there must be no risk of breakage in this withdrawal.

The author then states that about seven years since the Messrs. Huggett set themselves to devise means of making horse-nails by machinery, and that, having secured the support of Mr. Moser, a factory was provided and machines were made. These, as machines, answered well; but the nails produced, though fair to the eye, were unsound: after endeavouring for a long time to remedy the defect, the attempt was abandoned, so far as that particular class of machine was concerned, and the whole of them were pulled up and thrown into the scrap-heap. The Messrs. Huggett then again applied themselves to their task and invented another machine, which turned out nails, not only perfect in appearance, but also perfect in fact. Thereupon a large factory was filled with machinery; but again failure and loss were to result, not from the imperfection of the nail, but from the inability of the machine to withstand the wear and tear incident to the particular nature of its action. Once more the scrap-heap was the destination of property which had cost thousands of pounds.

For a third time the Messrs. Huggett set themselves to invent a mode of making horse-nails by machinery, which they trusted would not only produce a thoroughly good nail, but would endure the test of daily use.

About three years since Mr. Moser consulted the author and asked him to advise as to whether or not a third adventure of capital should be made.

Having thoroughly investigated the subject, including in this investigation an inquiry into the causes of the two former failures, the author came to the conclusion and advised that a trial (a commercial one, but on a small scale, to the extent of about £5000 of outlay) should be given to this third invention of the Messrs. Huggett. The advice was followed, and the result has been highly satisfactory, the working of the process having proved a complete success.

The author then proceeds to describe the mode of manufacture now followed in carrying out this third invention.

The material used is the Swedish charcoal iron nail-rod, which is heated in a Siemens Regenerative Gas-furnace, a double furnace having two working doors (attended by two men) at each end.

Six pieces of the nail-rod, in lengths of about 2 feet 6 inches, are charged into the furnace at each working door. Thirty seconds suffice to raise them to a high welding-heat.

The workman who has charged a parcel of rods then (by means of a pair of tongs) takes out the pieces one by one and jerks them endways down an inclined shoot, by which they are conducted to a pair of rolls, which seize them in succession as they are presented and roll them through. The author then points out that these rolls, and the operations they perform upon the iron, are of the very highest importance in the manufacture, that, in fact, they lie at the root of it.

The author then describes that the rolls are pattern-rolls, and are so constructed that when working together they leave a channel or groove for the passage of the nail-rod, which passage, while parallel and of uniform size, so far as regards its sideway dimensions, varies in its height as the revolution of the rolls brings round the different parts of their patterned surfaces. By the action of the patterned surfaces, the rod which had entered the rolls a piece of mere parallel iron about 2 feet 6 inches long, leaves them as a rod of nail-blanks 7 feet in length, and made up of numerous alternate prominences and depressions, occurring at distances apart corresponding to the length of two nails, each prominence being intended for two heads and each depression for two shanks.

Obviously a change of shape so violent must be done at a high heat; and, looking at the small section of the iron, the only way to retain the heat during the whole rolling is to run the rolls at a great velocity, so that there shall

not be time for the iron to cool. With this view the rolls are driven at as many as 550 revolutions per minute, giving (the rolls being about 7 inches in diameter) a surface speed of about 1000 feet.

The author then mentions how consecutive work is kept up by the two men taking care to alternate their charges of rods into the furnace, so that while those first put in are being rolled a second lot are heating. The operations of feeding and of rolling each take thirty seconds.

The author then enters into certain mechanical details as to how the rolls are arranged to support the endway strain put upon them by the attempt of the plastic iron in the grooves to spread sideways under the vertical pressure.

The author then points out that it is an essential condition of obtaining good work from pattern-rolls that they should not be overheated, that they should not be injured by the nearly fluid oxide adhering to the heated iron, and that the objects produced should be able to leave the rolls with facility. He then describes how the Messrs. Huggett attained all these desiderata by causing a stream of coal-tar to impinge upon the very channel or working chamber of the rolls, which stream abstracts the heat, affords a lubricant, and at the same time supplies a film (a mere microscopic one) of carbon between the heated iron and the surface of the rolls.

The author next remarks upon the necessity of keeping such implements as pattern-rolls in perfect repair, and states that with this object it has been wisely determined never to allow the rolls to run for more than "one shift" without adjustment; this being done daily, and being performed by the aid of appropriate tools, is a simple and expeditious operation, not more than $\frac{1}{100}$ of an inch in thickness having to be removed.

The author then proceeds to describe that the heated rod of nail-blanks, after they are shot out of the rolls into the receiving-tray, are pulled straight, and that when cold they are presented, edgeways up, to the action of a pair of plain surface-rollers, which press on the top of the prominences, and thus diminish their height and proportionately increase their breadth, by which means the metal in the prominences is made to project in the direction of the width of the shank of the nail, as well as in the previous direction, that of its depth, and is thus disposed in the most suitable manner to be subsequently formed into the heads.

The author then reverts to the employment in this manufacture of the Siemens Regenerative Gas-furnace, and points out how essential it is that for rolling (such as that which has been described) there should be none of that variation of size which must occur by waste in an ordinary furnace; and he shows how, by the ability which the Siemens furnace affords of giving not only a non-oxidizing but even a reducing flame, the risk of waste is reduced to a minimum; and states, so successful has the application of this apparatus been to this particular manufacture, that the total of furnace and rolling-mill waste is only 3 per cent., which, looking at the small size of the iron heated, and the large proportion the surface bears therefore to the weight, is an almost incredibly favourable result.

The author then, proceeding with the description of the manufacture, states that the flattened rods of nail-blanks are next taken to the cutting-machine, which has three pairs of cutters, so that at each stroke it severs the rod through the prominences, so as to cut out of each the future heads of two nails, and severs it through the thin parts to produce the shanks of those nails, and the cut being on a level forms at the same time the rudimentary point, while the third pair of cutters shears off a small portion from the point, and thus regulates the nail to the exact length.

The author then describes the peculiar contrivances by which perfect squareness of cut is obtained in these particular machines.

The separated nail-blanks, it is stated, are then examined, and any that may be imperfect are thrown out. After this the perfect blanks are subjected to friction one against another in a slowly revolving cylinder called a "Rumbler," after which they are annealed, certain precautions rendered necessary by the character of the material and the nature of the article to be produced being taken.

The author then describes the next process, the one that gives the true shape to the head. This, it is stated, is done in a machine having a vertically reciprocating

plunger, carrying the heading-tool, which operates upon the upper end of the blank, spreading it out so as to fill a cavity of the shape of the head. Such a cavity is formed in each one of a pair of dies, twelve in number, inserted about the periphery of a strong bolster-wheel carried on a horizontal axis. The blanks to be headed are fed by the attendant into the dies, and by the intermittent motion of the wheel are brought at the right time under the action of the heading-tool. There is a contrivance by which the halves of the disks are grasped firmly together while the pressure is being put on the head; but this grasp is taken off after the head is formed, so as to allow the headed blank to be readily discharged.

An efficient but simple mode of repairing the heading-dies is then pointed out.

After the heading the blanks are again annealed, and they are then taken to the final machine, the shaping-machine.

The author describes that this machine is almost identical in its construction with that of the "Header," the difference being that the heading-tool in the vertical punch is replaced by one of a proper form to give the flat-way shape, while a pair of side presses are added which produce the side-way finish.

After this operation the nails are submitted to a final examination, then to two consecutive "rumblings," the first one being with a gritty substance to produce extra attrition; and after these two "rumblings" the nails are taken to a revolving cylinder, like a coffee-roaster, in which they are heated to such a temperature as to produce a deep blue colour. They are then ready for the market.

The author concludes his paper by stating that the works, which are situated at Nine Elms, near London, are provided with machinery which is now turning out five tons of nails per week, that he understands that the machinery is speedily about to be very much added to, to increase the production; and he then expresses his opinion that the result of the invention will be not only, as he trusts, a profit to the spirited inventors and to the capitalist (Mr. Moser), but also a benefit to the public, and a benefit even to the persons now employed in the hand manufacture of horse-nails, which, being a trade that demands scarcely any plant, is carried on in the cottages of the workpeople, is very badly remunerated, is the subject of very great disturbances, in the way of trade disputes, and is altogether in a most unsatisfactory condition, so far as regards both the remuneration and comfort of the workpeople.

On the Nant-y-glo Coal-cutting Machine. By Dr. W. J. Clapp.

Progress of the Through Railway to India. By Hyde Clarke, *C.E., F.S.S., Corr. Mem. Vienna Institution of Engineers.*

In continuation of last year's Report it was stated that in European Turkey 341 miles are open from Sarem Bey to Philipopoli, and Adrianople to Constantinople, with a sea branch to Dedeh-Aghadj, in the archipelago. Beyond Constantinople, in Asiatic Turkey, the line is at work to Ismid. The only gap is now between the Austrian railways and Sarem Bey.

The alternative line is open from Banyaluka to Doberlin in Bosnia, and from Keupruly to Salonika.

Reference was made to the old Persian concessions having passed into the hands of Baron de Reuter, and to the preparations being made for proceeding with the Russian connecting section from Reshd, on the Caspian, to Teheran.

On Brain's System of Mining by means of Boring-machinery, Dynamite, and Electric Blasting. By Samuel Davis.

Further Results on the Working of Locomotives with Heated Air and Steam. By R. Eaton.

On the "Duty" of Arrastres in reducing Gold Ore in Italy. *By* C. Le Neve Foster, *B.A., D.Sc., F.G.S.*

After defining "duty" as the percentage of the total gold contents extracted by the machines, the author proceeded to give the results of experiments carried on by him for three years (1869-72) at the Piedimulera Reduction Works, situated at the foot of the Val Anzasca, and belonging to the Pestarena Gold-Mining Company. The machines used for reducing the ore are improved arrastres, on a plan invented by Messrs. T. and J. Roberts and H. Hoskings.

The ore for amalgamation, containing from 9 to 13 dwts. per ton, was very carefully sampled and assayed before it went to the arrastres. The average result for the first year was, that the arrastres extracted 73·3 per cent. of the gold in the ore, in the second year 78·5 per cent., and in the third year 82 per cent. The author called attention to the fact that the average duty of the six winter months, when the average temperature of the water supplied to the mills was 39° F., was always higher than the average duty of the six summer months, when the average temperature of the water supplied to the mills was 52° F. He considered that the fall in duty for the summer months was due to the water being charged with mud from the glaciers, whereas in winter the water was quite clear. The fact, however, was instanced to show that high duties are quite compatible with cold water.

On the Irrigation of the Casale District. *By* P. Le Neve Foster, *Jun.*

On the Mechanical Treatment of Fibrous Substances. *By* S. C. Lister.

On Napier's Pressure Log.* *By* James R. Napier, *F.R.S.*

On Stone-dressing in Bradford. *By* Archibald Neill.

There is little machinery at work in the stone trade of the district; for, although stone-moulding and -dressing machines have been at work on Bath, Portland, and other soft stones of the southern counties, they are not adapted to work the hard stone of this district, the great grinding-power of the stone on the tools being a considerable difficulty. We have the ordinary steam stone-saws, that are very useful, enabling the builder to cut the stone in such a manner as always to secure that when set in the building it shall be on its natural bed. At the same time it is a great economizer of material, saving fully 10 per cent. Coulter and Harpin's and the ordinary rubbing-tables are in use, and answer well for flags, landings, and common work. Still we want machines that will perform the more expensive portions of masons' work, such as moulding, sinking, and circular work. The author exhibited sketches of four machines which he had constructed—two for working stone, and two for wood. Though simple, they are yet capable of doing a considerable amount of work. In No. 1 the stone is placed on a travelling table, and carried against the cutters held on a revolving wheel. The stone is then cut to a true face. The grind on the tool is considerable, but the expense in steel and sharpening is not so much as in the ordinary masons' chisel. The work is done at one third the cost of hand labour. No. 2 machine is for rubbing stone to a true and smooth face. The stone is roughly punched to a shape and fixed on a table. This table is moved before the face of a revolving plate, while weights draw the stone up against the face of the plate. Sand and water are put on, and the work is done at about one third the cost of hand labour. This machine is simple and cheap, and requires little power to drive it. The author concluded by exhibiting drawings of two machines for working wood.

* Published *in extenso* in the 'Engineer' for Oct. 3, 1873.

On the Sand-Blast Process for Cutting and Ornamenting Stone, Glass, and other Hard Substances. By W. E. Newton, *C.E.*

In this process a stream of sand is introduced into a rapid jet of steam or air so as to acquire a high velocity, and is then directed upon any hard or brittle substance so as to cut or wear away its surface.

For work, such as cutting or ornamenting stone, where a considerable quantity of material is to be removed, a steam-jet of from 60 to 120 lbs. pressure has generally been used as the propelling agent. The sand is introduced by a central tube of about $\frac{1}{8}$-inch bore, and the steam issues from an annular passage surrounding the sand-tube. The impetus of the steam then drives the sand through a chilled iron tube $\frac{1}{8}$-inch bore and about 6 inches long, imparting velocity to it in the passage, and the sand finally strikes upon the stone, which is held about 1 inch distant when a deep narrow cut is desired, but may be 10 or 15 inches distant when a broad surface is to be operated on.

This chilled iron tube is the only part of the apparatus which is worn away by the cutting-action of the sand; it is so arranged as to be easily replaced, and lasts about ten hours.

To produce ornaments or inscriptions on stone, either in relief or intaglio, a stencil or template of iron or caoutchouc is held on or cemented to the stone, and the sand-jet is moved with an even and steady motion over the whole surface, so that all the exposed parts may be operated upon and cut to the same depth.

The skill and time of the artist may be devoted exclusively to making the stencil or template; this being prepared, the most elaborate and intricate designs can be cut as rapidly as the most simple. A template of cast iron $\frac{3}{16}$ inch thick will serve to make 100 cuts $\frac{3}{16}$ inch deep in marble, and will then be worn down to about $\frac{1}{16}$ inch thickness. Malleable iron templates last about four times as long as cast iron.

The durability of caoutchouc as compared with stone, under these circumstances, is remarkable. A stencil made of a sheet of vulcanized caoutchouc about $\frac{1}{16}$ inch thick, exposed to sand driven by 50 lbs. steam at 2 feet distance, has lasted with scarcely perceptible wear while 50 cuts were made in marble, each cut being about $\frac{1}{4}$ inch deep, or about $12\frac{1}{2}$ inches in all, or 200 times the thickness of the caoutchouc. With a supply of steam equal to about $1\frac{1}{2}$ horse-power, at a pressure of about 100 lbs., the cutting effect per minute was about $1\frac{1}{2}$ cubic inch of granite, or 4 cubic inches of marble, or 10 cubic inches of rather soft sandstone. To cut a face or level surface on a rough stone, the sand-jet is made to cut a groove about 1 inch deep along the whole length of the stone; the overhanging edge is then broken off with the hammer, and the jet is advanced an inch and a new groove is cut, and its overhanging edge is broken off, and so on.

To cut a deep channel, as in quarrying, two jets set at divergent angles are used. These jets make parallel grooves about 3 inches apart, leaving between them a narrow fin or tongue of stone, which is broken off by a tool; the jets are then advanced and new grooves cut. The sides of the channel are parallel, and it is made wide enough to permit the whole jet-pipe to enter, so that it may be cut to any desired depth, say 8 or 10 feet.

When effects of a more delicate nature are desired, as when engraving on glass, only small quantities of material are to be removed; the blast of air from an ordinary rotary fan will then be found sufficient as the propelling medium.

Sand driven by an air-blast of the pressure of 4 inches of water will completely grind or depolish the surface of glass in ten seconds.

If the glass be covered by a stencil of paper or lace, or by a design drawn in any tough elastic substance, such as half-dried oil, paint, or gum, a picture will be engraved on the surface by the impact of the sand on the exposed parts.

Photographic copies, in bichromated gelatin, from delicate line engravings, have been thus faithfully reproduced on glass.

In photographic pictures in gelatin, taken from nature, the lights and shadows produce films of gelatin of different degrees of thickness. A carefully regulated sand-blast will act upon the glass beneath these films more or less powerfully in proportion to the thickness of the films, and the half-tones or gradations of light and shade are thus produced on the glass.

If we apply the sand-blast to a cake of resin on which a picture has been produced by photography in gelatin, or drawn by hand in oil or gum, the bare parts of the surface may be cut away to any desired depth. The lines left in relief will be well supported, their base being broader than their top, there being no under cutting, as is apt to occur in etching on metal with acid.

An electrotype from this matrix can be printed from in an ordinary press as from a stereotype plate.

The sand-blast has been applied to cutting ornaments in wood, cleaning metals from sand, scale, &c., cleaning the fronts of buildings, graining or frosting metals, cutting and dressing mill-stones, and a variety of other purposes.

On the Burleigh Rock-drill. *By* JOHN PLANT, *F.G.S.*

On the Resistance of the Screw Propeller as affected by Immersion.* *By* Prof. OSBORNE REYNOLDS, *M.A.*

On the Friction of Shot as affected by different kinds of Rifling. *By* Prof. OSBORNE REYNOLDS, *M.A.*

On the Economical Generation of Steam. *By* ROBERT SUTCLIFFE.

The steam-boiler as at present constructed seems to be only partially adapted for the economical generation of steam, and this because it is expected to fulfil somewhat dissimilar conditions. It is required as a generator, as a reservoir, and receptacle, and it must resist a pressure always in excess of that which it is intended to put upon the steam-engine. As a reservoir for steam it must have cubic capacity, which of itself diminishes its power of resisting pressure; and to enable it to resist pressure the plates must be made stronger, and the additional thickness of metal which is thus interposed between the fire and the water diminishes the efficiency of the boiler as a generator of steam.

As the pressure is increased, the cubic capacity of the boiler must be reduced, thus restricting the reservoir room; whilst if the reservoir space be enlarged, its capability of resisting pressure is diminished; it is thus found that incompatibilities are involved, and that in trying to accomplish one object, another of primary importance must be sacrificed.

It would therefore seem that the boiler ought to be treated as a compound machine, and be constructed with adjuncts, so that each part may perform its appropriate functions, and separately contribute to the efficiency of the boiler in its threefold capacity as a generator, as a reservoir, and as a vessel capable of containing steam at a great pressure.

Where intermittent and irregular motion only is required, large steam spaces may not be of much importance; but in spinning-mills, where extreme and unintermitting steadiness of motion is required, considerable steam space is indispensable, for the reason that a reservoir of force is as necessary in the boiler as a reservoir of motion is necessary in the fly-wheel of the steam-engine.

The boiler which combines the maximum of advantages with the minimum of drawbacks for mill purposes seems to be the ordinary double-flued Lancashire boiler, strongly made and double-riveted and about seven feet in diameter, and with the flues well filled with Galloway tubes, upon which the heat impinges at right angles, and being intercepted is at once communicated to the water inside the boiler.

This boiler is in itself a good generator; it affords the requisite reservoir room for steam, and can be made to stand a considerable pressure. It is simple in construction, and accessible in all its parts for cleaning and other purposes; but of itself it

* Published in the 'Engineer' for Oct. 3, 1873.

cannot intercept and utilize all the heat which is produced, no inconsiderable portion of which escapes into the waste-flue, and thence to the chimney. This heat should be intercepted and utilized by a series of pipes placed in the flue, so that the minimum quantity may find its way to the chimney. Wrought-iron steam-tubing is the best for this purpose; it will stand a great pressure, and the metal being thin, the waste heat is at once communicated to the feed-water inside the pipes; and, further, wrought-iron pipes do not incur much liability to fracture on account of alternating temperature, or from any uncertain or violent action of the pumps, or misadventure from other causes.

In thus endeavouring to utilize fuel to the utmost, other difficulties present themselves. The chimney-draft is produced by hot air; and if this heat is arrested, chilled, and absorbed by coming into contact with obstacles in the shape of pipes, the surfaces of which are kept comparatively cold by the feed-water inside, the chimney-draft is correspondingly diminished and injured; and if the heat were altogether absorbed, there would be no chimney-draft at all; therefore, in many cases, the injury to the draft is the direct measure of the utility of the appliances for the absorption of the waste heat. In this contingency it is well to have recourse to the fan-blast to improve the draft, and thus to supply the requisite quantity of oxygen by mechanical means.

I have learnt from experience that machine firing with the aid of the fan-blast is the most effective. The fuel is supplied continuously, ignition is more regular and intense, and the chill and consequent destruction of heat caused by frequently opening the furnace-doors is avoided. Steam is raised with a greater certainty and at less cost both in fuel and wages by this mode of firing. There is also an economy in grate-bars, and greater facility in preventing and consuming smoke. To assist the fireman in preventing smoke, it is well to have a reflector of plate glass fixed in some convenient place outside the building, so that he may see at any moment and at a glance how the chimney top is behaving. No efficient work can be performed without good tools, and these in return require the care and watchful intelligence of the workman.

We cannot economize fuel to the utmost without proportionately diminishing the power of the boiler as a generator of steam. If the boiler be furiously fired without any regard to economy in fuel, all other things being equal, more steam will be raised, though at a greater cost, than if the firing were done carefully. If the heat be extracted to the utmost possible extent, the boiler of necessity does less work, and the steam raised is less in quantity; and a similar fact appears in the economical utilization of steam in the steam-engine. In the boiler, as in the engine, conflicting conditions arise, that whilst we seek to satisfy the one, we of necessity sacrifice the other. In the production of heat it may also be borne in mind that the engine is a valuable adjunct to the boiler, to which it may be made to restore a portion of its waste heat, which has already done its work as a motive power.

The Economical Utilization of Steam. *By* Robert Sutcliffe.

The primary object which the steam-engine has to secure in spinning- and weaving-mills is extreme regularity and steadiness of motion; compared with this economy in fuel, important though it be, is a subordinate consideration. Thus, whilst theory tells us to use one engine only with enlarged cylinder area, a pair of engines working at right angles give a steadiness of motion and equability of pressure unattainable in the other case; hence the pair is adopted, and the theoretical advantages of a single engine are discarded. When steam is used at a high degree of expansion with a single engine, the irregularity of motion is in many cases painfully apparent. Weight and velocity in the fly-wheel may diminish the defect, but cannot entirely neutralize it; but with a pair of engines we can work with high expansion combined with great steadiness of motion. Where steadiness of motion is not of primary importance, economy in fuel may be the first consideration. In this case we may work with a single engine with steam put upon the piston at high pressure, cut off early in the stroke and wrought to a high degree of expansion. But here our finest calculations are rudely interrupted

in practice. The engine at a certain pressure and a certain cut-off and at a certain velocity may be calculated to do its work at the greatest economy in steam; but if the exigencies of trade require more work to be got out of the engine, these conditions are at once disturbed, and the theoretical mechanic tells me that I am not upon the best footing. The precaution must also be taken that the engine must in all cases be above its work; but whether above or below its work a theoretical drawback is involved: if underweighted to begin with, the load, as a rule, is bit by bit increased until it is overweighted; and this, not that the manufacturer is ignorant, but that he has sacrificed theoretical advantages to the exigencies of his trade.

Where steadiness of motion is required, it seems preferable to use a pair instead of a single engine; and it is advantageous also to use the steam expansively up to a certain point, although by so doing the mechanical result obtainable from the engine is proportionately diminished. Where high pressures are used it is better to have a compound engine, using the steam throughout the double stroke by means of a smaller cylinder exhausting into a larger one. To arrange differently involves a great waste of metal in the engine, and very heavy pressure upon the bearings, especially when close to the dead centres; for the engine must be constructed to resist the maximum strain, even though it be during an inconsiderable portion of the stroke only. I am acquainted with a case where high pressure, high rate of expansion, combined with great steadiness of motion were required; and in order that this threefold object should be accomplished, a pair of condensing-engines were compounded with a pair of high-pressure engines, the four engines working all in a block, each engine receiving only its own strain, and all coupled together by means of the pinions upon the line-shaft. Here we have four engines dividing amongst them, with the most satisfactory results, the work which might be done by a single engine of larger dimensions. The strain is equalized over the different cranks, fly-wheel, shafts, segments, wheels, and bearings; there is the most exquisite steadiness of motion, great economy of fuel, and a complete absence of breakdowns and accidents. These four engines have now been working in combination several years without accident or breakdown; and this, in itself, is no slight advantage. Greater economy in steam might be realized by cutting off earlier in the stroke, and more work might be got from the engine by cutting off later; but it is not always easy, neither may it be desirable, to alter existing arrangements. The fact which has already been noted in the boiler reappears in the steam-engine—that by economizing fuel to the utmost less work is got out of the boiler, so by economizing steam to the utmost, less work is got out of the steam-engine. If the pressure upon the piston be 60 lbs. to the inch continued throughout the entire stroke, the maximum amount of work is got from the engine; but in this case there is no gain from expansion: but if the initial pressure be 60 lbs., and the cut-off be at one eighth of the stroke, the gain from expansion is considerable; but the average pressure is 23 lbs. only, being considerably less than half the work which the engine is able and which it was constructed to perform. Every part of the engine will have been made to stand safely the maximum pressure of 60 lbs., without which it would break to pieces at once; the difference between this and the minimum is so much strength thrown away. Thus we find that, like every thing else in the world, economy itself must be purchased, and sometimes at too great a cost; for even as regards expansion there is a limit at which it ceases to be profitable.

The steam-engine may be made into a valuable adjunct to the boiler as an instrument for the generation of heat, by retaining and restoring to the boiler a considerable portion of the waste heat, which has already done its work as a motive power. Primarily this is done by using a portion of the injection-water; but the beneficial result may be considerably enhanced by causing this water to travel through a series of copper pipes which receive the impact of the steam on its passage from the cylinder to the condenser. A considerable amount of waste heat may thus be recovered and utilized, and the injection-water itself is also correspondingly economized.

Compounding under its different aspects is here recommended; nor is there any thing in it opposed to scientific or mechanical simplicity. Compound the boiler

proper with its attendant economizer; compound the steam-engine by its high pressure and condensing-cylinders; compound the motion, and thus render it more equable, by having a pair of engines; and compound the condenser in order to recover and utilize the waste heat from the steam and return it to the boiler in the feed-water additionally heated. These plans and combinations have successfully stood the test of a lengthened experience, and they are hereby recommended for public use.

On the Centre-rail Railway. By W. Cave Thomas.

This differs from other projects bearing a similar title, in which carriages and engines are swung, pannierwise, on either side of a raised rail, beam, or wire. Mr. Thomas has utilized the scientific principles which maintain the bicycle and its rider balanced when in motion. In Mr. Thomas's central-rail railway the engine and carriages are on a level with, or above, the central rail, and run upon double-flanged wheels ranged in one line down the longitudinal centre of the train. Balance-wheels, which may be applied in several different ways, are only used to prevent undue swaying when the train is in motion, or to preserve its balance when starting or stopping.

The central rail in combination with two lines of wooden sleepers, parallel with and slightly lower in their level than the central rail, to receive the touch of side balance-wheels, is the form recommended for the colonies. In this case three lines of metals, of the same level, are laid for some little distance in and out of stations.

On the Prevention of Incrustation in Steam-Boilers. By John Waugh.

On the Advancement of Science by Industrial Invention. By Thomas Webster, *Q.C., F.R.S.*

On the Assimilation of the Patent Systems of Great Britain and of the United States. By Thomas Webster, *Q.C., F.R.S.*

On a Form of Channel Steamer. By John White.

On the History, Progress, and Description of the Bowling Ironworks.* By Joseph Willcock, *Chief Engineer.*

There are several indications in the Bradford district that iron was manufactured here at a remote period of antiquity. It is believed that the Romans both got and worked ironstone in the neighbourhood. Dr. Richardson, the eminent botanist, writing to Hearne nearly 200 years ago, stated that iron was made in the neighbourhood of Bierley, two or three miles from Bradford, in the time of the Romans, as upon a heap of cinders being removed to repair the highway there, he had discovered a quantity of copper Roman coins. The ironstone cropped out in several places, and in many others it lay very near the surface, so that with making "bell pits" there would be no difficulty in getting the ironstone. Within a few miles of Bradford there are at work the old established and still flourishing works of Kirkstall Forge, which claim to have been the first establishment to use rolls for slitting iron into nail-rods, this process having been carried on there so far back as the year 1594. Thus Bradford and the district may claim to have made Roman implements of warfare, and most probably Saxon, Norman, and old English ones likewise. In fact this department was carried on up to a very recent period, when the Bowling and Low-Moor Works manufactured cast-iron guns and mortars.

* The paper will be published *in extenso* by the Bowling Ironworks Company.

At or about 1784 James Watt was completing his invention of a rotary motion steam-engine, the introduction of which was only required to inaugurate a new era in the history of the iron trade. It was about this time that the Bowling Ironworks were commenced, the first furnace being blown in in the year 1788. Even before that date, however, we have records of some part of the works being in existence, and doing a limited trade in foundry and smith work. But as works for the smelting of ores, they date from the year 1788, three years in advance of the sister works at Low Moor. This was the beginning of the trade of the best Yorkshire irons, now so famous for their qualities through the entire civilized world. The Bowling Ironworks may properly be considered, therefore, the pioneer of that great prosperity which has rendered Bradford famous amongst the commercial marts of the world.

The population of the borough when the Bowling works were started could only have been about 10,000, as thirteen years later (in 1801) it was not more than 13,264, whereas the present population is over 150,000. The establishing of works of this kind, at which employment for a considerable number of men would be ensured, must at that period have been regarded as an event of much importance. John Sturges, of Sandal, Wakefield, an ironmaster of repute, was the first to broach the idea of establishing ironworks on the ground they now stand, and to his knowledge of the necessary minerals to produce a superior iron is to be attributed the choice of the situation.

The engine originally erected for blowing purposes was burnt down a few years after it had been at work, and was replaced by the one called the "Old Blast Engine" now existing. This was considered to be a great improvement upon the first one, as the valve-gear was made self-acting. Below the engine, and constructed in massive masonry work, was made the air-chamber for equalizing the pressure of the blast. A bar-mill and a plate-mill were started soon afterwards, and were also driven by a steam-engine, a considerable portion of which was constructed on the spot. We find it stated in Smiles's 'Lives of Boulton and Watt' that notice was given to the Bowling Ironworks, near Bradford, of proceedings against the company for the recovery of dues. On this the Bowling Company offered to treat, and young Watt went down to Leeds for the purpose of meeting the representatives of the Bowling Company on the subject. On the 24th February, 1796, he wrote his friend Matthew Robinson Boulton as follows:—"Enclosed you have a copy of the treaty of peace, not amity, concluded at Leeds on Saturday last between me, Minister Plenipotentiary to your Highness on the one part, and the Bowling Pirates in person on the other part. I hope you will ratify the terms, as you will see they are founded entirely upon the principle of indemnity for the past and security for the future." On referring to the private ledger of these works of that date, we find that the treaty of peace referred to was purchased at the price of £1640.

The substratum around Bowling is part of the most extensive and valuable coal-field in England, stretching from Derby or Nottingham to this district, a distance of sixty miles, and ranging about eight miles broad. The seam of coal called the "better bed," which is one of the valuable elements necessary for the production of the best quality of iron, is seated upon a peculiar hard siliceous sandstone termed "galliard," immediately above the black-bed coal, and resting upon it is an argillaceous stratum of the mean thickness of two yards, in which lies imbedded, in irregular layers, the valuable ironstone of this district. The stone wears a dark brown appearance, and yields about 32 per cent. of iron. Both coals are caking coals, and moderately hard. The ash of the black-bed coal is of a dark purple gold colour, similar to roasted pyrites. This coal contains a very large percentage of pyrites in a state of intimate mixture in the coal, so that it cannot be seen; the ash fuses readily, is slightly alkaline (due to lime), and contains sulphide of iron and a very large quantity of oxide. The works comprise six cold-blast furnaces, from which about 360 tons of pig-iron are run per week, five refineries, twenty-one puddling-furnaces, forty heating-furnaces, an extensive forge, a tyre-mill for rolling steel and iron weldless tyres, one guide-mill, one bar-mill, with 15-in. rolls, and two plate-mills. A third new plate-mill is nearly completed. The powerful reversing-engines to give motion to this mill are on the principle introduced by

Mr. John Ramsbottom, late of Crewe Works; and when the mill is completed, plates can be rolled of the largest superficial area ever yet attempted. There are also extensive steelworks for making crucible steel, having about 100 pot-furnaces, which are now in process of extension and improvement by the erection of new furnaces on the Siemens and Siemens-Martin principle, to be worked by Siemens's regenerative gas-furnaces. Engineering works comprise foundry, smithy, boiler-fitting, millwright, wheelwright, and fitting shops.

The Bowling Company itself supplies almost all the coal and ironstone which it consumes, its collieries extending five or six miles in various directions, and the main pits being connected together and with the ironworks by tramways worked with wire ropes. The total length of these tramways is 21 miles, the number of pits 42, and the number of hands employed in them is more than 2000. To work the pits 61 steam-engines are required, having cylinders varying from 7 to 70 inches in diameter, and to supply them with steam 81 steam-boilers are required of from 10- to 50-horse power each. In the ironworks are 3 blast-engines, with blowing cylinders varying from 76 to 84 inches in diameter, and 14 engines of from 20- to 60-horse power, to give motion to the various machines, besides numerous small engines driving separate machines and pumping water for the boilers. The number of steam-hammers is 13, and helve-hammers 2. The supply of steam is maintained by 33 boilers, of from 20- to 50-horse power each. The number of hands employed at the ironworks is upwards of 1000, thus making a total of upwards of 3000. The yield per cent. on the raw ore is 32 per cent. of iron, and on the calcined ore 42 per cent. of iron. The following are the relative quantities of minerals for producing one ton of Bowling pig-iron:—Raw ore, 3 tons 3 cwt. 3 qrs. 27 lbs.; calcined ore, 2 tons 7 cwt. 1 qr. 26 lbs.; limestone ore, 18 cwt. 2 qrs. 12 lbs.; coke ore, 2 tons 5 cwt. 0 qr. 9 lbs. The quantity of pig-iron used to produce one ton of bar-iron (finished) is 1 ton 12 cwt. 1 qr. 25 lbs. The limestone is obtained from Skipton, and is called locally "Skipton old rock."

The following is an analysis of Bowling pig-iron:—

	per cent.
Carbon as graphite	3·361
Carbon combined	·393
Silicium	1·382
Iron	92·952
Manganese	1·475
Phosphorus	·602
Sulphur	·063
Titanium	trace
	100·152

The sulphur in all the samples varies only very slightly, and may in fact be considered identical, the difference in the results not being more than those due to the errors of experiment. The phosphorus in all the samples exists in precisely the same quantity, the whole of this element present in the ore combining with the iron. The author exhibited a sketch of the original blast-furnace at Bowling, now in existence, and working to within two or three weeks, presuming it might be interesting to some of the members of the Association. He has been told by some of the oldest inhabitants of Bowling that there was only one tuyere at first; but two have now been used for many years, the nozzles being $2\frac{3}{4}$ in. diameter, and the pressure of blast supplied to this and the other furnaces 32 ounces. The iron for plates and bars is taken direct to the refineries or oxidizing hearths. The metal is placed upon the hearth, covered with coke, and a blast is forced over the surface. Two tons of refined or plate metal are produced from each charge, which is run into moulds cooled by water, the refined metal being about 2 inches thick and 12 feet long by 4 feet broad. From the refineries the plate, or refined metal, is taken to the puddling-furnaces for conversion into malleable iron in the usual manner, by charges of about 3 cwt. at a time, and each puddling-furnace is charged ten times a day. The quality of the iron necessitates more attention from the puddler than the commoner classes of iron; and to insure the extra attention and

a uniform quality, a premium is given to the puddlers who have produced the best specimens during a turn. The puddled iron is taken under the steam-hammer to knock out the slag and impurities, and is made into what are called "stampings" and "nobblins." The stampings are broken into several pieces under fall-hammers, piled, heated, taken under a steam-hammer, and made into blooms or billets, in which state they are taken to the bar- or guide-mill, reheated, and rolled into round or square bars, angle-irons, rods, or such other shapes as may be required. The nobblins are piled, heated, taken under the steam-hammer, and made into blooms or slabs of various sizes, and afterwards to the plate-mill, where they are reheated and rolled into plates. From stampings are made the Bowling-iron weldless tyres. A hole about 5 inches in diameter is punched through the centre of the bloom, forming it into a ring of iron. The ring thus made is hooked on the back of an anvil, and is hammered with a suitably shaped hammer-head to raise up the flange, the ring being constantly rotated on the beck between the blows of the hammer, so that all parts may be evenly worked. At the end of this process the ring begins to have some resemblance to a tyre, and is then rolled out.

The steelworks were erected in the year 1866, and the steel manufactured is crucible steel, produced in the ordinary manner in furnaces heated by coke. The iron used is scrap from Bowling plates, and its conversion into steel is effected by the addition of suitable quantities of carbon, chiefly introduced by Spiegeleisen, and also by a mixture of steel scrap. Of the steel produced, a part is used for making tyres from ingots in a similar manner to iron tyres and general forgings; and a considerable portion is used for making castings of all descriptions, where strength, with lightness, is the desideratum. Arrangements are now being made, and are partly completed, for applying Siemens's gas process for melting the crucible steel in suitable furnaces; and a Siemens-Martin's furnace is also in course of erection for the conversion of pig-iron into steel, which will produce four tons of steel at one operation.

The engineering is done in an extensive range of buildings, where the whole of the work and new plant required to keep the collieries and works described in repair are made. This department is also devoted to the construction of engines, boilers, &c. for the market. In the model-room (one of the finest in the country) is a model from which the first wheel was cast for Blenkinsop's locomotive. The boiler-shop is now being extended, so as to be capable of producing from two to three boilers per week, besides all descriptions of plate-flanging. The foundry has been recently rebuilt upon the old site.

The distinguished qualities of the Bowling iron are hardness with great pliability, homogeneity and uniformity of texture, capability of withstanding the action of fire and of receiving a brilliant polish, it being used extensively in the Sheffield trades on account of the last-named virtue. Works established in the infancy of the iron trade, and producing a superior quality of metal (quality being always preferred to quantity whenever the alternative presented itself), must naturally be disposed to conservatism. Besides, repeated experiences have proved the necessity of keeping to the original mode of working with the minerals and iron. It is rarely known to what purposes or tests the iron may be put to on leaving the premises; but it is known that it will have to withstand usage such as no common iron or any other iron but charcoal iron perhaps could do, and it was for the latter that the Bowling iron was originally manufactured as a substitute. Keeping in view the production of a uniform quality, changes of whatever description have been jealously regarded, and those that have been made have only been arrived at by very gradual stages.

APPENDIX.

Notes of some Experiments on the Conducting-powers for Heat of certain Rocks, with Remarks on the Geological Aspects of the Investigation. By Prof. A. S. Herschel *and* G. A. Lebour, *F.G.S.*

A subject of considerable interest in a physical and geological point of view, as illustrating the questions of underground temperature that have recently occupied the attention of a Committee of the British Association, presented itself as open to much more extensive experimental investigation than perhaps, from the absence of any immediate practical applications of its results, it has hitherto been thought worthy to receive. The object which the authors of this communication proposed to themselves was to determine experimentally the actual conducting-powers for heat of as many well-defined and commonly occurring species of geological rocks as they could conveniently obtain, and submit to the test of some suitable and practical method of experiment. A collection of more than twenty specimens of rocks of the best-marked descriptions were for this purpose selected at the well-known Marble and Stone Works at Newcastle-on-Tyne, of Messrs. Walker, Emley, and Beall, who at the same time undertook to reduce the blocks (together with some additional materials obtained elsewhere) to a uniform size and shape, to which they are all gauged with the greatest care. The plates are circular, five inches in diameter and half an inch thick, and were thus chosen as being nearly of the same dimensions as those employed by Peclet in his investigations of the conducting-powers of various substances for heat. Considerable labour and risk, however, is incurred in working plates of granite and the harder stones of such thinness; and (as the result has shown) the measurements of their heat-conducting powers would have been rendered both more exact and easier had a thickness of about one inch instead of half an inch been adopted for the plates. A list of the specimens employed is annexed below; and it will be seen that among rocks of very wide distribution but of more friable materials, as chalk, coal, sand, or marl, and some more recent sedimentary contributions to the earth's crust, no attempt to include them in these measurements has yet been made.

The purpose of the present note is simply to establish from the preliminary observations the general BAD conducting-powers of the harder rocks, and to corroborate, in the case of a few examples that were numerically reduced, the conclusions of a similar description that were obtained by Peclet.

Description of the Apparatus.—In order to heat the rocks, a flat-topped circular tin boiler was provided of the same diameter as the rock plates, upon which they could be laid so as to be exposed on their lower side to the heat of boiling water. The steam produced by the water at the bottom of the boiler rises through a central tube to the top, where it circulates in a steam-space formed by a perforated diaphragm placed round the top of the tube, and it emerges from the side of the boiler at the bottom of the annular space formed between the boiler and the central tube. The upper part of the boiler is surrounded to about an inch in depth (the depth of the steam-space) by a thick ring of wood resting upon a projecting ledge of the boiler, and protecting it, as well as the slab of rock placed inside it upon the flat lid of the boiler, from loss of heat to the surrounding air. The ring of wood projects above the rock so as to receive a flat-bottomed tin vessel (shaped like a conical flask) of water, of the same diameter as the rock plate at the base, and contracting at the top to a narrow neck, in which a thermometer is inserted by a cork. When the apparatus is in use, a light packing of cotton-wool is inserted between the wooden ring and its contents, to keep them more effectually from contact with the outer air.

Mode of conducting the Experiments, and their Results.—The heat-conducting power of a substance being measured by the quantity of heat that passes through a plate of it of known thickness and cross section at a given difference of temperature between its two faces of which the interval can be measured, it might at first be

supposed that by including the rock to be tested between the temperature of boiling water on one side, and that of spring-cold water in the thermometer flask on the other side, the required conditions of a known difference of temperature would be attained, while the rate of ascent of the thermometer in the colder vessel at the same time marks the quantity of heat transmitted. But so far are the two surfaces of the rock specimens from taking up the temperatures of the metal plates with which they are in contact, that, with the rough means of determining their real temperatures which were first employed, *no sensible difference whatever* could be observed between them! The small difference which without doubt exists is sufficient to transmit the small quantity of heat which passes, and the whole rock plate assumes very nearly the mean degree of temperature between that of the boiler on one side, and of the cold-water flask on its other side. In this state of uncertainty regarding the effective difference of temperature, it is quite obvious that no conclusions of the nature of a numerical comparison can be made between the various rock sections; but a trial of each was yet made in the apparatus in order to determine the rate of flow of the transmitted heat.

Out of six specimens thus tried, slate plates cut parallel to the plane of cleavage transmitted the heat faster than any of the others. When the flow of heat had become uniform, the water was raised 1° F. in thirty-two seconds. With marble, sandstone, granite, and serpentine, about thirty-nine seconds were required to raise it by the same amount. The greatest resistance to the passage of heat was offered by two specimens of shale (grey and black) from the Coal-measures in the neighbourhood of Newcastle, which occupied forty-eight or fifty seconds in raising the water one degree, or half as long again as the time taken by the plate of slate. The black shale is highly fossiliferous, and it allows heat to pass more slowly than the other harder and more compact grey species of the same kind of rock.

These experiments were not extended further, as uncertainty regarding the real temperatures to which the surfaces of the plates were exposed introduced an unknown element into the question of their conducting-powers. Some experiments, however, were made, which makes it probable that this difficulty can be removed. It was found that the flow of heat is very little diminished by lifting the slabs of rock off the heating plate, and also separating them to various distances from the thermometric flask by introducing felt wads of a few different thicknesses between the surfaces. A film of air (as already observed by Peclet, or of water if steam or water is used to heat the plates) adheres to and protects their surfaces by its bad conducting-power from becoming hot or cold, and thus opposes a certain resistance to the passage of the heat. It is not improbable that the resistance thus produced is the same for fresh cut and smoothly ground surfaces of all the different kinds of rock; and by using different thicknesses of one of them its amount might be determined and employed as a correction in estimating the conducting-powers of all the other kinds of rock subjected to the trials. Although the results of this method would certainly be of the greatest interest in connexion with many practical contrivances for transmitting heat from liquid or gaseous to solid bodies, and the reverse, yet a less circuitous method, as affording the desired results more speedily to present them to the British Association, seemed to be preferable, and the following direct observations were therefore adopted in their stead.

A slender iron wire was joined at its two ends by twisting them on to two pieces of similar platinum wire, which were connected by long copper wires with the terminals of a Thomson's reflecting galvanometer provided with a millimetre scale. When the two platinum and iron junctions were warmed to different degrees, the galvanometer showed the difference between their temperatures on its scale. The twisted junctions were fastened on the tops of two small corks, so that they could be pressed against the surfaces of the rock; and in one arrangement the corks were attached to the heating and cooling plates of the heat-apparatus, and the thermoelectric couples were thus supported by the corks so as to touch the rocks. In this position they recorded the state of temperature of the plate of stone *in situ*, while the heat conducted through it was at the same time being measured by the thermometer. The divisions of the galvanometer scale were themselves estimated in

Fahrenheit degrees by inserting a double tin lid between the corks, under the two opposite faces of which water of different degrees of temperature was made to circulate, and the temperature of the water was made known by thermometers inserted in the lids. The other arrangement consisted in fixing the corks to the ends of a pair of wooden tongs, so that the rock plate could be pressed between them as soon as it was taken off the heater. It was in a first trial of this last arrangement that no perceptible signs of heat-difference could be observed between the rock-faces. To increase the actual difference, however, the edge of one of the stone plates was surrounded with a band of paper, and the upper surface was then covered with mercury, upon which the thermometer-flask was placed, this having also been filled with mercury instead of water to accelerate conduction. On taking the rock (a plate of white marble) out of the apparatus after this treatment, and testing its thermal difference with the galvanometer, it was found that one surface was about 7° F. hotter than the other, while the flask containing 9 lbs. of mercury was heated 1° F. in about ten seconds. This corresponds to the passage of 330 heat-units per hour through a 1-inch plate of the same rock (1 square foot in surface-area), with the same difference of temperature on its opposite sides of about 7° F. For a difference of 1° the transmission of heat in the same time would be 47 heat-units, while the value obtained by Peclet for fine-grained white marble was 28 heat-units per hour. It is evident that some of the difference of temperature between the surfaces of the plate subsided and disappeared in lifting it out of the heating-apparatus and transferring it to the galvanometer, so as to make the conducting-power of the plate appear to be about half as great again as its known value. The galvanometer, which at first marked 7°, rapidly sank to zero as the rock was moved about between the cork projections.

The other disposition of the iron-platinum couples (on corks fixed to the heating and absorbing plates) touching the rock-surfaces during the heating operation, was found to introduce errors in the opposite direction by showing, apparently from the conducting-power of the cork supports, greater temperature differences of the surfaces than can reasonably be supposed to have existed. Thus with the same plate of white marble a temperature difference of 50° F. was recorded, instead of 7° F. as in the former case; while 264 heat-units per hour was the rate of conduction through a plate of standard size for that difference, corresponding to only $5\frac{1}{4}$ heat-units for a difference of one degree, and not exceeding a fifth part of the value found by Peclet. The same process was tried with the two kinds of shale, and showed, as before, that their conducting-power is much less than that of fine-grained marble, the quantities found for their conducting-powers being $2\frac{1}{2}$ and 2 heat-units per hour, or less than half as great as that of marble. The heat-conducting power of ordinary calcareous stone is similarly found by Peclet to be about half as great as that of fine-grained marble, the latter varying between 22 and 28, and the former between 11 and 13; and the results of further tiials will, without doubt, confirm more closely the exact values which he assigns.

Had time allowed the experiments to be repeated with a new arrangement of the apparatus, the sources of error peculiar to each of the above methods would have been readily removed, as their origin is in each case easily explained; and another series will be undertaken with the excellent collection of rock sections that have now been provided for them. In drawing up this description of the first trials to which they were subjected, it is sufficiently interesting to observe that not only the relative values but also the absolute quantities of the heat-conducting powers of different substances obtained by Peclet are approximately confirmed, since certain kinds of stone are found to have less than half the conducting-powers of other kinds; and in the case of marble the quantity of heat passing through a square-foot plate one inch thick per hour, with a difference of 1° F. between the opposite faces, was found in two trials (giving the conductivity respectively in excess and defect) to be between 42 or 47 and 5 or 7 heat-units, while the value of certain marbles found by Peclet varied from 22 to 28 heat-units. The corresponding numbers obtained by Peclet for certain metals, as copper, iron, and lead, are 515, 233, 113 heat-units per hour, or many times greater than those of terrestrial rocks. The latter occupy an intermediate place between the metals and such substances as the various

kinds of wood, of which the conducting-power is between 1 and 2 heat-units per hour.

The following is a list of the rocks of which circular sections of the above uniform size have been provided for this examination:—

1. Grey (Aberdeenshire) granite.
2. Red Cornish serpentine.
3. Green Cornish serpentine.
4. Whinstone.
5. Gannister.
6. Slate (parallel to the cleavage).
7. English alabaster.
8. Italian white-veined marble.
9. Sicilian white-veined marble.
10. Devonshire red marble.
11. Cork red marble.
12. Irish green marble.
13. Kilkenny fossil marble.
14. Frosterly fossil marble.
15. Cumberland (Dent) marble.
16. Congleton second gritstone.
17. Red Galashiels sandstone.
18. Kenton sandstone.
19. Heworth sandstone.
20. Prudham sandstone.
21. Fossiliferous black shale. } from near New-castle.
22. Common grey shale. } from near New-castle.

A. S. HERSCHEL.

The foregoing observations are not only of very great interest from a purely physical point of view, but I venture to think have a certain geological importance, especially as regards underground temperature and all the numerous geological problems depending on it. Even with the meagre array of actual readings which it has been possible to arrive at in time for this Meeting, certain results have been obtained which give, I think, great promise of the value of these investigations when we carry them on with the modified apparatus already described. It will scarcely be necessary at this early stage of the work to do more than call the attention of the Section to its theoretical bearings as regards geology.

In the first place, it seems to be proved by our experiments that the conducting-power of different rocks varies strictly according to their lithological character. Very crystalline rocks, such as granite and serpentine and statuary marble, allowed heat to pass rapidly through them; slate plates, with their uncrystalline compact structure, had a still higher degree of conductivity. The crystalline nature of a rock alone is not, therefore, the lithological test of its conductivity. The lowest powers of conductivity were found to belong, among the specimens experimented on, to shale; the black shale, which was lower than the grey, is softer and more argillaceous than it, the grey shale having a considerable admixture of arenaceous matter and mica. The difference, however, between these two was so slight that, in the present preliminary researches, when much must be allowed to error, it may be left out of consideration altogether. It would appear, then, from these facts, that a certain compactness, accompanied by cleavage, is favourable to the passage of heat through rocks; and if it be admitted that what is true for small thicknesses is also true for great ones, we may be justified in supposing that the vast masses of clay-slate, and perhaps to a still greater extent their more metamorphosed and crystalline schists (which we know to extend to great depths), are so many points of weakness which must have their influence in the secular cooling of the earth. On the other hand, points of resistance may be assumed to exist and to be formed by the great sedimentary accumulations of shale, and probably also of clay and other argillaceous unaltered rocks. In a column, therefore, composed in part of cleaved clay-slate and in part of shale, the easy passage of the internal heat outward through the first would be checked through the other in the ratio, roughly speaking, of 5 to 8. This becomes a stupendous difference when we apply it to the thicknesses we are acquainted with. If we imagine a thick covering of shale or clay, or some other rock with a very *low* conductivity, which has arrested in its course the heat passing up to it through underlying rocks with a high degree of conductivity—if we imagine such a surface-covering removed (as we know that they frequently have been) by denudation, it is evident that the equilibrium of the heat-resisting covering of the earth will be altered, not only at this particular spot, but also wherever the material removed is being redeposited. We may say, in other words, that we stand nearer the great central source of heat when we stand on slate than we do when we stand

on shale. When the experiments in hand have been repeated and largely added to, it is hoped that this accession or loss of conducting-power in connexion with the ordinary agents of geological force may be (perhaps only approximately) expressed numerically. One might even suppose that the disturbance of heat-transmitting equilibrium has something to do with the distribution of volcanic and thermal phenomena. Without, however, treading further on such dangerously speculative ground, we may hope, by dint of careful experiment of the kind now brought before the Section, to throw some light on the curious discrepancy which is constantly being noted in observations of underground temperature taken at different places, the *rate* of transmission of heat (for which we hope to make in time lists and tables) being manifestly intimately connected with that subject.

G. A. Lebour.

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CONTENTS:—Rev. B. Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on "The Motion and Sounds of the Heart," by the London Committee of the British Association, for 1839-40;—Prof. Schonbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838 to Nov. 1st, 1839;—W. Thompson, Report on the Fauna of Ireland: Div. *Vertebrata*;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at 13s. 6d.*

CONTENTS:—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M.D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific cooperation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Com-

mittee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles;—Reports on the Determination of the Mean Value of Railway Constants;—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s*. 6*d*.

CONTENTS:—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants,—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain,—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at £1.*

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at 12s.*

CONTENTS:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at 15s.*

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Muller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at 15s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840 to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at 16s. 6d.*

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850 to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at 15s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53; —James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued); —Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55; —Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report

on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at 15s.*

CONTENTS:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{-\alpha} t \dfrac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $\alpha^{t|+1}$ désignant le produit des t facteurs $\alpha\,(\alpha+1)\,(\alpha+2)$ &c....$(\alpha+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry;—John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at 20s.*

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the

Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857-58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles's paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15*s.*

Contents:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—A. Thomson, Esq., of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, Lanarkshire,—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858-59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858-59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air;—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15*s.*

Contents:—James Glaisher, Report on Observations of Luminous Meteors, 1859-60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Professor Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of

Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders ;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860 ;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II. ;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel ;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena ;—Second Report of the Committee on Steamship Performance ;—Interim Report on the Gauging of Water by Triangular Notches ;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at £1.*

CONTENTS :—James Glaisher, Report on Observations of Luminous Meteors ;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I. ;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships ;—Warren De la Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting ;—B. Stewart, on the Theory of Exchanges, and its recent extension ;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District ;—Dr. J. Hunt, on Ethno-Climatology ; or, the Acclimatization of Man ;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches ;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops ;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea ;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand ;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles ;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon ;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon ;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee ;—Third Report of the Committee on Steamship Performance ;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours ;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations ;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859; —J. Oldham, Continuation of Report on Steam Navigation at Hull ;—Professor G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland ;—Professor Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind ;—Colonel Sykes, Report of the Balloon Committee ;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England ;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland ;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities ;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders ;—Report of the Committee on the Law of Patents ;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING, at Cambridge, October 1862, *Published at £1.*

CONTENTS :—James Glaisher, Report on Observations of Luminous Meteors, 1861–62 ;—G. B. Airy, on the Strains in the Interior of Beams ;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee ;—Report on Tidal Observations on the Humber ;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences ;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza ;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank ;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine ;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance ;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Do-

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Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at £1 5s.*

CONTENTS:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and of the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for Exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Akin, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Professor Airy, Report on Steam-boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published* at 18s.

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at £1 5s.*

CONTENTS:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds;—Report on further Researches in the Lingula-flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—A. G. Findlay, on the Bed of the Ocean;—Professor A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Professor Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at £1 4s.*

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the "Menevian Group," and the other Formations at St. David's, Pembrokeshire;—J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth;—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the penetration of Iron-clad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at £1 6s.*

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Me-

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Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at* £1 5*s*.

CONTENTS:—Report of the Lunar Committee;—Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds;—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the desirability of Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures;—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published* at £1 2*s*.

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Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE **FORTIETH MEETING**, at Liverpool, September 1870, *Published at* 18*s*.

CONTENTS:—Report on Steam-boiler Explosions;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland;—Report on the Sedimentary Deposits of the River Onny;—Report on the Chemical Nature of Cast Iron;—Report on the practicability of establishing "A Close Time" for the protection of Indigenous Animals;—Report on Standards of Electrical Resistance;—Sixth Report on Kent's Cavern;—Third Report on Underground Temperature;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on the Stability, Propulsion, and Sea-going Qualities of Ships;—Report on Earthquakes in Scotland;—Report on the Treatment and Utilization of Sewage;—Report on Observations of Luminous Meteors, 1869-70;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On a new Steam-power Meter;—Report on the Action of the Methyl and Allied Series;—Report of the Rainfall Committee;—Report on the Heat generated in the Blood in the process of Arterialization;—Report on the best means of providing for Uniformity of Weights and Measures.

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PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s*.

CONTENTS:—Seventh Report on Kent's Cavern;—Fourth Report on Underground Temperature;—Report on Observations of Luminous Meteors, 1870-71;—Fifth Report on the Structure and Classification of the Fossil Crustacea;—Report for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison;—Report for the purpose of Superintending the publication of Abstracts of Chemical papers;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Second Provisional Report on the Thermal Conductivity of Metals;—Report on the Rainfall of the British Isles;—Third Report on the British Fossil Corals;—Report on the Heat generated in the Blood during the process of Arterialization;—Report of the Committee appointed to consider the subject of physiological Experimentation;—Report on the Physiological Action of Organic Chemical Compounds;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on Steam-Boiler Explosions;—Report on the Treatment and Utilization of Sewage;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine;—Report on the practicability of establishing a "Close Time" for the protection of Indigenous Animals;—Report on Earthquakes in Scotland; Report on the best means of providing for a Uniformity of Weights and Measures;—Report on Tidal Observations.

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PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s*.

CONTENTS:—Report on the Gaussian Constants for the Year 1829;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—Eighth Report on Kent's Cavern;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Fourth Report on the Fauna of South Devon;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers;—Third Report on Steam-Boiler Explosions;—Report on Observations of Luminous Meteors, 1871-72;—Experiments on the Surface-friction experienced by a Plane moving through water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer;—Fourth Report on the Treatment and Utilization of Sewage;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships and Currents;—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the

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Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

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J. P. GASSIOT, Esq., D.C.L., LL.D., F.R.S.
Professor PHILLIPS, D.C.L., LL.D., F.R.S.

PRESIDENT ELECT.

PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S.

VICE-PRESIDENTS ELECT.

The Right Hon. the EARL OF ENNISKILLEN, D.C.L., F.R.S.
The Right Hon. the EARL OF ROSSE, F.R.S., F.R.A.S.
Sir RICHARD WALLACE, Bart., M.P.
The Rev. Dr. HENRY, President of Queen's College, Belfast.
Dr. T. ANDREWS, F.R.S., F.C.S.
Rev. Dr. ROBINSON, F.R.S., F.R.A.S.
Professor STOKES, D.C.L., Sec.R.S.

LOCAL SECRETARIES FOR THE MEETING AT BELFAST.

W. QUARTUS EWART, Esq.
Dr. P. REDFERN.
T. SINCLAIR, Esq., J.P.

LOCAL TREASURER FOR THE MEETING AT BELFAST.

WILLIAM J. C. ALLEN, Esq.

ORDINARY MEMBERS OF THE COUNCIL.

BEDDOE, JOHN, M.D., F.R.S.
BRAMWELL, F. J., Esq., C.E., F.R.S.
DEBUS, Dr. H., F.R.S.
DE LA RUE, WARREN, Esq., D.C.L., F.R.S.
EVANS, JOHN, Esq., F.R.S.
FITCH, J. G., Esq., M.A.
FLOWER, Professor W. H., F.R.S.
FOSTER, Prof. G. C., F.R.S.
GALTON, FRANCIS, Esq., F.R.S.
HIRST, Dr. T. ARCHER, F.R.S.
HUGGINS, WILLIAM, Esq., D.C.L., F.R.S.
JEFFREYS, J. GWYN, Esq., F.R.S.
LOCKYER, J. N., Esq., F.R.S.
MAXWELL, Professor J. CLERK, F.R.S.
MERRIFIELD, C. W., Esq., F.R.S.
NORTHCOTE, Rt. Hon. Sir STAFFORD H., Bt., M.P.
OMMANNEY, Admiral E., C.B., F.R.S.
PENGELLY, W., Esq., F.R.S.
PRESTWICH, J., Esq., F.R.S.
RUSSELL, Dr. W. J., F.R.S.
SCLATER, Dr. P. L., F.R.S.
SIEMENS, C. W., Esq., D.C.L., F.R.S.
SMITH, Professor H. J. S., F.R.S.
STRACHEY, Major-General, F.R.S.
STRANGE, Lieut.-Colonel A., F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The President and President Elect, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries, the General Treasurer, the Trustees, and the Presidents of former years, viz.:—

The Duke of Devonshire.
The Rev. T. R. Robinson, D.D.
Sir G. B. Airy, Astronomer Royal.
General Sir E. Sabine, K.C.B.
The Earl of Harrowby.
The Duke of Argyll.
The Rev. H. Lloyd, D.D.
Richard Owen, M.D., D.C.L.
Sir W. Fairbairn, Bart., LL.D.
The Rev. Professor Willis, F.R.S.
Sir W. G. Armstrong, C.B., LL.D.
Sir Chas. Lyell, Bart., M.A., LL.D.
Professor Phillips, M.A., D.C.L.
Sir William R. Grove, F.R.S.
The Duke of Buccleuch, K.B.
Dr. Joseph D. Hooker, D.C.L.
Professor Stokes, D.C.L.
Prof. Huxley, LL.D., Sec.R.S.
Prof. Sir W. Thomson, D.C.L.
Dr. Carpenter, F.R.S.

GENERAL SECRETARIES.

Capt. DOUGLAS GALTON, C.B., R.E., F.R.S., F.G.S., 12 Chester Street, Grosvenor Place, London, S.W.
Prof. MICHAEL FOSTER, M.D., F.R.S., Trinity College, Cambridge.

ASSISTANT GENERAL SECRETARY.

GEORGE GRIFFITH, Esq., M.A., F.C.S., Harrow-on the-hill, Middlesex.

GENERAL TREASURER.

WILLIAM SPOTTISWOODE, Esq., M.A., LL.D., F.R.S., F.R.G.S., 50 Grosvenor Place, London, S.W.

AUDITORS.

J. Gwyn Jeffreys, Esq., F.R.S. — Professor Phillips, F.R.S. — Professor Sylvester, F.R.S.

*

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1874.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of Residence should be sent to the Assistant General Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough-house, Woodberry Down, Stoke Newington, London, N.
1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.
1863. *ABEL, FREDERICK AUGUSTUS, F.R.S., F.C.S., Director of the Chemical Establishment of the War Department, Royal Arsenal, Woolwich, S.E.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1873. §Abercrombie, William. 5 Fairmount, Bradford.
1863. *Abernethy, James. 2 Delahay-street, Westminster, London, S.W.
1873. §Abernethy, James. Ferry-hill, Aberdeen.
1860. §Abernethy, Robert. Ferry-hill, Aberdeen.
1873. *Abney, Captain, R.E. St. Margaret's, Rochester.
1854. ‡Abraham, John. 87 Bold-street, Liverpool.
1873. §Ackroyd, Samuel. Greaves-street, Little Horton, Bradford.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
*ACLAND, HENRY W. D., M.A., M.D., LL.D., F.R.S., F.R.G.S., Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.
Adair, John. 13 Merrion-square North, Dublin.
1872. §ADAMS, A. LEITH, M.A., M.B., F.R.S., F.G.S., Staff Surgeon-Major. 30 Bloomfield-street, Westbourne-terrace, W.; and Junior United Service Club, Charles-street, St. James's, S.W.
*ADAMS, JOHN COUCH, M.A., D.C.L., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.

Year of Election.

1871. §Adams, John R. 15 Old Jewry Chambers, London, E.C.
1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., Professor of Natural Philosophy and Astronomy in King's College, London. 9 Notting-hill-square, London, W.
1873. §Adams-Acton, John. Margatta House, 103 Marylebone-road, N.W.
ADDERLEY, The Right Hon. Sir CHARLES BOWYER, M.P. Hams-hall Coleshill, Warwickshire.
Adelaide, Augustus Short, D.D., Bishop of. South Australia.
1860. *Adie, Patrick. Grove Cottage, Barnes, London, S.W.
1865. *Adkins, Henry. The Firs, Edgbaston, Birmingham.
1845. ‡Ainslie, Rev. G., D.D., Master of Pembroke College. Pembroke Lodge, Cambridge.
1864. *Ainsworth, David. The Flosh, Cleator, Whitehaven.
1871. *Ainsworth, John Stirling. The Flosh, Cleator, Whitehaven.
Ainsworth, Peter. Smithills Hall, Bolton.
1842. *Ainsworth, Thomas. The Flosh, Cleator, Whitehaven.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Whitehaven.
1859. ‡AIRLIE, The Right Hon. the Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.
AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., Pres.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich.
1871. §Aitken, John. Darroch, Falkirk, N.B.
Akroyd, Edward. Bankfield, Halifax.
1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B. The Athenæum Club, Pall Mall, London, W.
1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.
1872. *Alcock, Thomas, M.D. Oakfield, Ashton-on-Mersey, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
ALDERSON, Sir JAMES, M.A., M.D., D.C.L., F.R.S., Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.
1857. ‡Aldridge, John, M.D. 20 Ranelagh-road, Dublin.
1859. ‡ALEXANDER, Major-General Sir JAMES EDWARD, C.B., K.C.L.S., F.R.A.S., F.R.G.S., F.R.S.E. Westerton, Bridge of Allan, N.B.
1873. §Alexander, Reginald, M.D. 13 Hallfield-road, Bradford.
1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.
1867. ‡Alison, George L. C. Dundee.
1863. ‡Allan, Miss. Bridge-street, Worcester.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.
Allan, William.
1871. §Allen, Alfred H., F.C.S. 1 Surrey-street, Sheffield.
1861. ‡Allen, Richard. Didsbury, near Manchester.
Allen, William. 50 Henry-street, Dublin.
1852. *ALLEN, WILLIAM J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*Allis, Thomas, F.L.S. Osbaldwick Hall, near York.
*ALLMAN, GEORGE J., M.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. 21 Marlborough-road, London, N.W.; and Athenæum Club, London, S.W.
1844. *Ambler, Henry. Watkinson Hall, near Halifax.
1873. §Ambler, John. North-park-road, Bradford, Yorkshire.

Year of Election

*Amery, John, F.S.A. Manor House, Eckington, Pershore.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1871. *Anderson, James. Battlefield House, Langside, Glasgow.
1852. ‡*Anderson, Sir James.*
1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
1850. ‡ANDERSON, PATRICK. 15 King-street, Dundee.
1850. ‡ANDERSON, THOMAS, M.D., Professor of Chemistry in the University of Glasgow.
1870. ‡Anderson, Thomas Darnley. West Dingle, Liverpool.
1853. *Anderson, William (Yr.). 2 Lennox-street, Edinburgh.
*ANDREWS, THOMAS, M.D., F.R.S., M.R.I.A., F.C.S., Vice-President of, and Professor of Chemistry in, Queen's College, Belfast.
1857. ‡Andrews, William. The Hill, Monkstown, Co. Dublin.
1859. ‡Angus, John. Town House, Aberdeen.
*ANSTED, DAVID THOMAS, M.A., F.R.S., F.G.S., F.R.G.S. 8 Duke-street, Adelphi, London, W.C.; and Melton, Suffolk.
1868. ‡ANSTIE, FRANCIS E., M.D. 16 Wimpole-street, London, W.
Anthony, John, M.D. Caius College, Cambridge.
APJOHN, JAMES, M.D., F.R.S., M.R.I.A., Professor of Chemistry, Trinity College, Dublin. South Hill, Blackrock, Co. Dublin.
1863. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *ARCHER, Professor THOMAS C., F.R.S.E., Director of the Museum of Science and Art. West Newington House, Edinburgh.
1851. ‡ARGYLL, His Grace the Duke of, K.T., LL.D., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, S.W.; and Inverary, Argyllshire.
1865. ‡Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.
1861. §Armitage, William. 7 Meal-street, Mosley-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1873. §Armstrong, Henry E., Ph.D., F.C.S. London Institution, Finsbury-circus, E.C.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *ARMSTRONG, Sir WILLIAM GEORGE, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Elswick Works, Newcastle-upon-Tyne.
1856. ‡Armstrong, William Jones, M.A. Mount Irwin, Tynna, Co. Armagh.
1868. ‡Arnold, Edward., F.C.S. Prince of Wales-road, Norwich.
1871. ‡Arnot, William, F.C.S. St. Margaret's, Kirkintilloch, N.B.
1870. §Arnott, Thomas Reid. Bramshill, Harlesden Green, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1873. §Ashton, John. Gorse Bank House, Windsor-road, Oldham.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
Aspland, Algernon Sydney. Glamorgan House, Durdham Down, Bristol.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Thomas. 4 Elm-court, Temple, London, E.C.
1872. §Atchison, Arthur T. Rose-hill, Dorking.
1873. §Atchison, D. G. Tyersall Hall, Yorkshire.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1866. ‡Atherton, J. H., F.C.S. Long-row, Nottingham.

Year of Election.

1865. ‡Atkin, Alfred. Griffin's-hill, Birmingham.
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *ATKINSON, EDMUND, F.C.S. 8 The Terrace, York Town, Surrey.
1863. *Atkinson, G. Clayton. 2 Windsor-terrace, Newcastle-on-Tyne.
1858. *Atkinson, John Hastings. 14 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 113 Abington-road, Kensington, London, W.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. Atkinson, William. Ashton Hayes, near Chester.
1863. *ATTFIELD, Professor J., Ph.D., F.C.S. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. Stoke Abbott Rectory, Beaminster, Dorset.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1865. *Avery, William Henry. Norfolk-road, Edgbaston, Birmingham.
1867. ‡Avison. Thomas, F.S.A. Fulwood Park, Liverpool.
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

Babbage, B. Herschel. 1 Dorset-street, Manchester-square, London, W.
*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
Bache, Rev. Samuel. 44 Frederick-street, Edgbaston, Birmingham.
Backhouse, Edmund. Darlington.
Backhouse, Thomas James. Sunderland.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1867. *Bagg, Stanley Clark. Fairmount Villa, Montreal, Canada.
1870. §Bailey, Dr. F. J. 51 Grove-street, Liverpool.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
1873. §Bain, James. 3 Park-terrace, Glasgow.
*Bain, Richard. Manor Hall, Forest Hill, London, S.E.
1865. ‡BAIN, Rev. W. J. Wellingborough.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, EDWARD. Belgrave-mansions, Grosvenor-gardens, London S.W.; and St. Ann's-hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1855. ‡BAINES, THOMAS, F.R.G.S. 35 Austen-street, King's Lynn, Norfolk.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. §Baker, Francis B. Sherwood-street, Nottingham.
1858. *Baker, Henry Granville. Bellevue, Horsforth, near Leeds.
1865. ‡Baker. James P. Wolverhampton.
1861. *Baker, John. Gatley-hill, Cheadle, Manchester.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. §Baker, William. 6 Taptonville, Sheffield.
1860. ‡Balding, James, M.R.C.S. Barkway, Royston, Hertfordshire.
1851. **Baldwin, The Hon. Robert.*

Year of
Election.

1871. ‡Balfour, Francis Maitland. Trinity College, Cambridge.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
*BALFOUR, JOHN HUTTON, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
*BALL, JOHN, F.R.S., F.L.S., M.R.I.A. 24 St. George's-road, Eccleston-square, London, S.W.
1866. *BALL, ROBERT STAWELL, M.A., LL.D., F.R.S., Professor of Applied Mathematics and Mechanics in the Royal College of Science of Ireland. 47 Wellington-place, Clyde-road, Dublin.
1863. ‡Ball, Thomas. Bramcote, Nottingham.
*Ball, William. Bruce-grove, Tottenham, London, N.; and Glen Rothay, near Ambleside, Westmoreland.
1870. ‡Balmain, William H., F.C.S. Spring Cottage, Great St. Helens, Lancashire.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1861. ‡Bannerman, James Alexander. Limefield House, Higher Broughton, near Manchester.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Kingslee, Farndon, Chester.
1859. ‡Barbour, George F. 11 George Square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A., M.R.A.S. Bury-hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
Barclay, James. Catrine, Ayrshire.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. **Barclay, Robert.*
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Notts.
1857. ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. Waterloo-road, Dublin.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡BARKLY, Sir HENRY, K.C.B., F.R.S. Bath.
1873. §Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
Barlow, Peter. 5 Great George-street, Dublin.
1857. ‡BARLOW, PETER WILLIAM, F.R.S., F.G.S. 8 Eliott-place, Blackheath, London, S.E.
1873. §BARLOW, W. H., C. E., F.R.S. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1868. §Barnes, Richard H. Care of Messrs. Collyer, 4 Bedford-row, London, W.C.
*Barnes, Thomas, M.D., F.R.S.E. Bunker's Hill, Carlisle.
Barnes, Thomas Addison. 40 Chester-street, Wrexham.
*Barnett, Richard, M.R.C.S. Avon-side, Coten End, Warwickshire.
1850. ‡Barr, Major-General, Bombay Army. Culter House, near Aberdeen. (Messrs. Forbes, Forbes & Co., 9 King William-street, London.)

Year of Election.

1861. *Barr, William R., F.G.S. Heaton Lodge, Heaton Mersey, near Manchester.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1872. *BARRETT, Professor W. F., F.C.S. Royal College of Science, Dublin.
1852. ‡Barrington, Edward. Fassaroe Bray, Co. Wicklow.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡BARRY, Rev. A., D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. 15 Pembridge-square, Bayswater, London, W.
Barstow, Thomas. Garrow-hill, near York.
1858. *Bartholomew, Charles. Castle-hill-house, Ealing, Middlesex, W.
1855. ‡Bartholomew, Hugh. New Gas-works, Glasgow.
1858. *Bartholomew, William Hamond. Albion Villa, Spencer-place, Leeds.
1873. §Bartley, George C. T. Ealing, Middlesex.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
*Barton, John. Stonehouse, Sallorgan-road, Booterstown, Dublin.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
1870. §BARUCHSON, ARNOLD. Blundell Sands, near Liverpool.
1858. *Barwick, John Marshall. Albion-place, Leeds; and Glenview, Shipley, near Leeds.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1861. ‡Bass, John H., F.G.S. 287 Camden-road, London, N.
1866. *BASSETT, HENRY. 215 Hampstead-road, London, N.W.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Professor of Pathological Anatomy to University College Hospital. 20 Queen Anne-street, London, W.
1848. ‡BATE, C. SPENCE, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1873. *Bateman, Daniel. Low Moor, near Bradford, Yorkshire.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
BATEMAN, JAMES, M.A., F.R.S., F.L.S., F.H.S. 9 Hyde Park Gate South, London, W.
1842. *BATEMAN, JOHN FREDERIC, C.E., F.R.S., F.G.S. 16 Great George-street, London, S.W.
1864. §BATES, HENRY WALTER, Assist.-Sec. R.G.S., F.L.S. Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡BATH AND WELLS, Lord ARTHUR HERVEY, Lord Bishop of.
1863. *Bathurst, Rev. W. H. Lydney Park, Gloucestershire.
1869. ‡Batten, John Winterbotham. 35 Palace-gardens-terrace, Kensington, London, S.W.
1863. §BAUERMAN, HENRY, F.G.S. 22 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1870. ‡BAXTER, R. DUDLEY, M.A. 6 Victoria-street, Westminster, S.W.; and Hampstead, N.W.
1867. ‡Baxter, William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1851. *Bayley, George. 2 Cowper's-court, Cornhill, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
1854. ‡Baylis, C. O., M.D. 22 Devonshire-road, Claughton, Birkenhead.
Bayly, John. 1 Brunswick-terrace, Plymouth.

Year of Election.

1860. *BEALE, LIONEL S., M.D., F.R.S., Professor of Pathological Anatomy in King's College. 61 Grosvenor-street, London, W.
1833. *BEAMISH, RICHARD, F.R.S. Moorend, Deane Park, Bournemouth.
1861. §Bean, William. Alfreton, Derbyshire.
1872. ‡Beanes, Edward, F.C.S. Avon House, Dulwich Common, Surrey.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Chemical Works, Rotherham.
1855. *Beaufort, W. Morris, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Capt. George G. India. (Army and Navy Club, Pall Mall, London, S.W.)
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. Whalley Range, Manchester.
1860. ‡BECKLES, SAMUEL H., F.R.S., F.G.S. 9 Grand-parade, St. Leonards-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D., F.R.S. Clifton, Bristol.
1873. §Behrens, Jacob. Springfield House, North-parade, Bradford.
1846. ‡BEKE, CHARLES T., Ph.D., F.S.A., F.R.G.S. London Institution, Finsbury-circus, London, E.C.
1865. *BELAVENETZ, I., Captain of the Russian Imperial Navy, F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-street, London, E.C.)
1847. *BELCHER, Admiral Sir EDWARD, K.C.B., F.R.A.S., F.R.G.S. 13 Dorset-street, Portman-square, London, W.
1873. §Bell, A. P. Vicarage, Sowerby Bridge, Yorkshire.
1871. ‡Bell, Archibald. Cleator, Carnforth.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Christ's Hospital, London, E.C.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *BELL, ISAAC LOWTHIAN, F.C.S. 4 Seamore-place, Hyde Park, W.
1871. *Bell, J. Carter, F.C.S. Cheadle, Cheshire.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
BELL, THOMAS, F.R.S., F.L.S., F.G.S. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. The Minories, Jesmond, Newcastle-on-Tyne.
1867. ‡Bell, Thomas. Belmont, Dundee.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. ‡Bellhouse, William Dawson. 1 Park-street, Leeds.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1866. *BELPER, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 88 Eaton-square, London, S.W.; and Kingston Hall, Derby.
1864. *Bendyshe, T. 8 Adelphi-terrace, Strand, London, W.C.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1871. ‡Bennett, F. J. 12 Hillmarten-road, Camden-road, London, N.
1838. ‡BENNETT, JOHN HUGHES, M.D., F.R.S.E., Professor of Institutes of Medicine in the University of Edinburgh. 1 Glenfinlas-street, Edinburgh.
1870. *Bennett, William. 109 Shaw-street, Liverpool.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 19 Tavistock-square, London, W.C.

Year of Election.

1857. ‡Benson, Charles. 11 Fitzwilliam-square-west, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡BENTHAM, GEORGE, F.R.S., Pres. L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 9 Portland-place, London, W.
1863. §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College. 91 Alexandra-road, St. John's-wood, London, N.W.
1868. ‡BERKELEY, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1866. ‡Berry, Rev. Arthur George. Monyash Parsonage, Bakewell, Derbyshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A. St. John's College, Cambridge.
1865. *BESSEMER, HENRY. Denmark-hill, Camberwell, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds.
1870. ‡Bickerton, A. W., F.C.S. The Penn, Portswood, Southampton.
1868. ‡BIDDER, GEORGE PARKER, C.E., F.R.G.S. 24 Great George-street, Westminster, S.W.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 17 Charles-street, Bath.
1855. ‡Billings, Robert William. 4 St. Mary's-road, Canonbury, London, N.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.; and Chislehurst, Kent.
1842. BINNEY, EDWARD WILLIAM, F.R.S., F.G.S. 40 Cross-street, Manchester.
1873. §Binns, J. Arthur. Manningham, Bradford, Yorkshire.
BIRCHALL, EDWIN. Airedale Cliff, Newley, Leeds.
Birchall, Henry. College House, Bradford.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
*Birks, Rev. Professor Thomas Rawson. 7 Brookside, Cambridge.
1842. *Birley, Richard. Seedley, Pendleton, Manchester.
1841. *BIRT, WILLIAM RADCLIFF, F.R.A.S. Cynthia-villa, Clarendon-road, Walthamstow, London, N.E.
1871. *BISCHOF, GUSTAV., Professor of Technical Chemistry in the Andersonian University, Glasgow. 234 George-street, Glasgow.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1859. ‡Blackie, John Stewart, Professor of Greek. Edinburgh.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 17 Stanhope-terrace, Glasgow.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London. E.C.
*BLACKWALL, Rev. JOHN, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1863. ‡*Blake, C. Carter, Ph.D., F.G.S.*
1849. *BLAKE, HENRY WOLLASTON, M.A., F.R.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.

Year of Election.

1845. ‡Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.
1861. §Blakiston, Matthew. 18 Wilton-crescent, S.W.
*Blakiston, Peyton, M.D., F.R.S. 55 Victoria-street, London, S.W.
1868. ‡BLANC, HENRY, M.D. 9 Bedford-street, Bedford-square, London, W.C.
1869. ‡Blanford, W. T., F.G.S., Geological Survey of India, Calcutta. (12 Keppel-street, Russell-square, London, W.C.)
*BLOMEFIELD, Rev. LEONARD, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
Blore, Edward, LL.D., F.R.S., F.S.A. 4 Manchester-square, London, W.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, Accrington.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1845. ‡*Bodmer, Rodolphe.*
1866. §Bogg, Thomas Wemyss. Louth, Lincolnshire.
1859. *BOHN, HENRY G., F.L.S., F.R.A.S., F.R.G.S., F.S.S. North End House, Twickenham.
1871. §Bohn, Mrs. North End House, Twickenham.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
1863. ‡*Bond, Francis T., M.D.*
Bond, Henry John Hayes, M.D. Cambridge.
1871. §Bonney, Rev. Thomas George, M.A., F.S.A., F.G.S. St. John's College, Cambridge.
Bonomi, Ignatius. 36 Blandford-square, London, N.W.
BONOMI, JOSEPH. Soane's Museum, 15 Lincoln's-Inn-fields, London, W.C.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1835. ‡Booth, Rev. James, LL.D., F.R.S., F.R.A.S. The Vicarage, Stone, near Aylesbury.
1861. *Booth, William. Hollybank, Cornbrook, Manchester.
1861. *Borchardt, Louis, M.D. Oxford Chambers, Oxford-street, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1863. ‡Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
BOSWORTH, Rev. JOSEPH, LL.D., F.R.S., F.S.A., M.R.I.A., Professor of Anglo-Saxon in the University of Oxford. Oxford.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1858. ‡Botterill, John. Burley, near Leeds.
1872. §Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. ‡BOTTOMLEY, JAMES THOMSON, M.A., F.C.S. The College, Glasgow.
Bottomley, William. Forbreda, Belfast.
1850. ‡Bouch, Thomas, C.E. Oxford-terrace, Edinburgh.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1868. ‡Boulton, W. S. Norwich.
1866. §Bourne, Stephen. Abberley Lodge, Hudstone-drive, Harrow.
1872. ‡Bovill, William Edward. 29 James-street, Buckingham-gate London, S.W.

Year of Election.

1870. §Bower, Anthony. Bowerdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1846. *Bowerbank, James Scott, LL.D., F.R.S., F.G.S., F.L.S., F.R.A.S. 2 East-ascent, St. Leonard's-on-Sea.
1856. *Bowlby, Miss F. E. 27 Lansdown-crescent, Cheltenham.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Princes' Park, Liverpool.
1869. ‡Bowring, J. C. Larkbeare, Exeter.
1863. ‡Bowron, James. South Stockton-on-Tees.
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡Boyle, Rev. G. D. Soho House, Handsworth, Birmingham.
1872. §Brabrook, E. W., F.S.A., Dir. A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Mount Henley, Sydenham Hill, S.E.
1870. §Brace, Edmund. 17 Water-street, Liverpool.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1861. *Bradshaw, William. Slade House, Levenshulme, Manchester.
1842. *Brady, Sir Antonio, F.G.S. Maryland Point, Stratford, E.
1857. *Brady, Cheyne, M.R.I.A. Four Courts, Co. Dublin.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡Brady, George S. 22 Fawcett-street, Sunderland.
1862. §Brady, Henry Bowman, F.L.S., F.G.S. 29 Mosley-street, Newcastle-on-Tyne.
1858. ‡*Brae, Andrew Edmund.*
1864. §Braham, Philip, F.C.S. 6 George-street, Bath.
1870. §Braidwood, Dr. Delemere-terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1865. §Bramwell, Frederick J., C.E., F.R.S. 37 Great George-street, London, S.W.
1872. §Bramwell, William J. 17 Prince Albert-street, Brighton.
Brancker, Rev. Thomas, M.A. Limington, Somerset.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1852. ‡Brazier, James S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *Breadalbane, The Right Hon. the Earl of. Taymouth Castle, N.B.; and Carlton Club, Pall Mall, London, S.W.
1859. ‡Brebner, Alexander C. Audit Office, Somerset House, London, W.C.
1867. ‡Brechin, The Right Rev. Alexander Penrose Forbes, Lord Bishop of, D.C.L. Castlehill, Dundee.
1873. §Breffit, Edgar. Castleford, near Normanton.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1869. ‡Brent, Colonel Robert. Woodbury, Exeter.
1860. ‡Brett, G. Salford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1865. §Brewin, William. Cirencester.
1867. ‡Bridgman, William Kenceley. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. §Brierley, Joseph, C.E. Blackburn.
1870. *Brigg, John. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.

Year of Election.

*BRIGGS, General JOHN, F.R.S., M.R.A.S., F.G.S. 2 Tenterden-street, Hanover-square, London, W.
1866. §Briggs, Joseph. Barrow-in-Furness.
1863. *BRIGHT, Sir CHARLES TILSTON, C.E., F.G.S., F.R.G.S., F.R.A.S. 69 Lancaster-gate, W.; and 26 Duke-street, London, S.W.
1870. †Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
BRIGHT, The Right Hon. John, M.P. Rochdale, Lancashire.
1868. ‡BRINE, Commander LINDESAY. Army and Navy Club, Pall Mall, London, S.W.
1842. Broadbent, Thomas. Marsden-square, Manchester.
1859. *BRODHURST, BERNARD EDWARD. 20 Grosvenor-street, Grosvenor-square, London, W.
1847. ‡BRODIE, Sir BENJAMIN C., Bart., M.A., D.C.L., F.R.S. Brockham Warren, Reigate.
1834. ‡BRODIE, Rev. JAMES, F.G.S. Monimail, Fifeshire.
1865. ‡BRODIE, Rev. PETER BELLENGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
Bromilow, Henry G. Merton Bank, Southport, Lancashire.
*BROOKE, CHARLES, M.A., F.R.S., Pres. R.M.S. 16 Fitzroy-square, London, W.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Drewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1863. §Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawstenstall, Manchester.
Brooks, William. Ordfall Hill, East Retford, Nottinghamshire.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1863. *Brough, Lionel H., F.G.S., one of Her Majesty's Inspectors of Coal-Mines. 11 West-mall, Clifton, Bristol.
*BROUN, JOHN ALLAN, F.R.S., late Astronomer to His Highness the Rajah of Travancore. 34 Reinsburg Strasse, Stuttgart.
1864. ‡Brown, Mrs. 1 Stratton-street, Piccadilly, London, W.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinbugh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 3 Mansfield-place, Glasgow.
1871. §Brown, David. 17 S. Norton-place, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1865. §Brown, Edwin, F.G.S. Burton-upon-Trent.
1858. §Brown, Henry, M.A., LL.D. Daisy Hill, Rawdon, Leeds.
1870. §BROWN, HORACE T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1870. §BROWN, J. CAMPBELL, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Berwick-on-Tweed.
1863. ‡Brown, John H. 29 Sandhill, Newcastle-on-Tyne.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. §BROWN, ROBERT, M.A., Ph.D., F.R.G.S. 4 Gladstone-terrace, Edinburgh.
1856. *BROWN, SAMUEL, V.P.S.S., F.R.G.S. The Elms, 42 Larkhall Rise, Clapham, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Lower Hardwick, Chepstow.
*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.
1855. ‡Brown, William. 11 Albany-place, Glasgow.

Year of
Election.

1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41 *a* New-street, Birmingham.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. §Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. §Browning, John, F.R.A.S. 111 Minories, London, E.
1855. §Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1853. ‡Brownlow, William B. Villa-place, Hull.
1863. *Brunel, H. M. 18 Duke-street, Westminster, S.W.
1863. ‡Brunel, J. 18 Duke-street, Westminster, S.W.
1871. §Brunnöw, F. Dunsink, Dublin.
1868. ‡Brunton, T. L. 23 Somerset-street, Portman-square, London, W.
1861. ‡Bryce, James. York Place, Higher Broughton, Manchester.
BRYCE, JAMES, M.A., LL.D., F.R.S.E., F.G.S. High School, Glasgow, and Bowes Hill, Blantyre, by Glasgow.
BRYCE, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡BUCCLEUCH and QUEENSBERRY, His Grace the Duke of, K.G., D.C.L., F.R.S.L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith Palace, Edinburgh.
1871. §BUCHAN, ALEXANDER. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
BUCHANAN, ANDREW, M.D. Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton cum Seacombe, Cheshire.
1871. ‡Buchanan, John Y. 10 Moray-place, Edinburgh.
*Buck, George Watson. Ramsay, Isle of Man.
1864. §BUCKLE, Rev. GEORGE, M.A. Twerton Vicarage, Bath.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1848. *BUCKMAN, Professor JAMES, F.L.S., F.G.S. Bradford Abbas, Sherbourne, Dorsetshire.
1869. ‡Bucknill, J. Hillmorton Hall, near Rugby.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S. Weycombe, Haslemere, Surrey.
1848. *BUDD, JAMES PALMER. Ystalyfera Iron Works, Swansea.
1871. §Bulloch, Matthew. 11 Park-circus, Glasgow.
1845. *BUNBURY, Sir CHARLES JAMES FOX, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1865. ‡Bunce, John Mackray. 'Journal Office,' New-street, Birmingham.
1863. §Bunning, T. Wood. 34 Grey-street, Newcastle-on-Tyne.
1842. *Burd, John. 37 Jewin-street, Aldersgate-street, London, E.C.
1869. ‡Burdett-Coutts, Baroness. Stratton-street, Piccadilly, London, W.
1872. *Burgess, Herbert. 62 High-street, Battle, Sussex.
1857. ‡*Burk, J. Lardner, LL.D.*
1865. ‡Burke, Luke. 5 Albert-terrace, Acton, London, W.
1869. **Burnell, Arthur Coke.*
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1872. §Burrows, Sir John Cordy. 62 Old Steine, Brighton.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *BUSK, GEORGE, F.R.S., V.P.L.S., F.G.S., Examiner in Comparative Anatomy in the University of London. 32 Harley-street, Cavendish-square, London, W.

Year of Election.

1857. ‡Butt, Isaac, Q.C., M.P. 64 Eccles-street, Dublin.
1855. *Buttery, Alexander W. Monkland Iron and Steel Company, Cardarroch, near Airdrie.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir T. Fowell. Warlies, Waltham Abbey.
1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. Orwell Works House, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh, Armagh.

CABBELL, BENJAMIN BOND, M.A., F.R.S., F.S.A., F.R.G.S. 1 Brick-court, Temple, E.C.; and 52 Portland-place, London, W.
1858. §Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1854. §Caine, Nathaniel. 38 Belvedere-road, Princes Park, Liverpool.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Messrs. Caird and Co., Greenock.
1857. ‡Cairnes, Professor, University College, London.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1853. ‡Calver, Captain E. K., R.N., F.R.S. 21 Norfolk-street, Sunderland.
1857. ‡Cameron, Charles A., M.D. 15 Pembroke-road, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1859. ‡Campbell, Rev. C. P., Principal of King's College, Aberdeen.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, W.C.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
*Campbell, Sir James. 129 Bath-street, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1872. §CAMPBELL, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford.
1859. ‡Campbell, William. Dunmore, Argyllshire.
1871. ‡Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana.
1862. *CAMPION, Rev. Dr. WILLIAM M. Queen's College, Cambridge.
1853. ‡*Camps, William, M.D.*
1868. *Cann, William. 9 Southernhay, Exeter.
1873. *Carbutt, Edward Hamer. Vulcan Iron Works, Bradford.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
CARLISLE, HARVEY GOODWIN, D.D., Lord Bishop of. Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
Carmichael, H. 18 Hume-street, Dublin.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
1871. §CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. §Carpenter, Herbert P. 56 Regent's Park-road, London, N.W.
*CARPENTER, PHILIP PEARSALL, B.A., Ph.D. Montreal, Canada.

Year of Election.

1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., M.D., F.R.S., F.L.S., F.G.S., Registrar of the University of London. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. Winifred House, Pembroke-road, Clifton, Bristol.
1842. *Carr, William, M.D., F.L.S., F.R.C.S. Lee Grove, Blackheath, S.E.
1861. *Carrick, Thomas. 5 Clarence-street, Manchester.
1867. §CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡CARTE, ALEXANDER, M.D. Royal Dublin Society, Dublin.
1868. §Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E. Long Carr, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 69 Elizabeth-street, Liverpool.
*CARTMELL, Rev. JAMES, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
Cartmell, Joseph, M.D. Carlisle.
1870. §Cartwright, Joshua. 70 King-street, Dukinfield.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. South-grove, Highgate, London, N.
1871. §Cash, Joseph. Bird Grove, Coventry.
1873. §Cash, William, Elmfield-terrace, Saville Park, Halifax.
1842. *Cassels, Rev. Andrew, M.A. Staincliff Hall, near Dewsbury, Yorkshire.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1866. ‡*Catton, Alfred, R., M.A., F.R.S.E.*
1873. *Cavendish, Lord Frederick. 21 Carlton House-terrace, S.W.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. 35 Park-square, Leeds.
1860. ‡CHADWICK, DAVID, M.P. 27 Belsize-park, London, N.W.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston-court, near Leominster.
1842. Chadwick, John. Broadfield, Rochdale.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*CHALLIS, Rev. JAMES, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡CHAMBERLAIN, J. H. Christ Church-buildings, Birmingham.
1868. ‡Chamberlin, Robert. Catton, Norwich.
1842. Chambers, George. High Green, Sheffield.
Chambers, John.

Year of Election.

1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. 4 New-street, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. Four Oaks Park, Sutton Coldfield, Birmingham.
1865. §Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1861. *Chapman, John. Hill End Mottram, Manchester.
1866. ‡Chapman, William. The Park, Nottingham.
1871. §Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1871. ‡Charles, T. C., M.D. Queen's College, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 113A Strand, London, W.C.
1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. 8 Gray's Inn-square, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, W.
*CHEVALLIER, Rev. TEMPLE, B.D., F.R.A.S., Professor of Mathematics and Astronomy in the University of Durham. The College, Durham.
1872. §CHICHESTER, The Right Hon. the Earl of. Stanmer House, Lewes.
CHICHESTER, RICHARD DURNFORD, Lord Bishop of. Chichester.
1865. **Child, Gilbert W., M.A., M.D., F.L.S.*
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
CHRISTISON, Sir ROBERT, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1870. ‡CHURCH, A. H., F.C.S., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1860. ‡Church, William Selby, M.A. 1 Harcourt-buildings, Temple, London, E.C.
1857. ‡Churchill, F., M.D. 15 Stephen's-green, Dublin.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. †Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855. §CLAPHAM, ROBERT CALVERT. Garsdon House, Garsdon, Newcastle-on-Tyne.
1869. §Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 11 Blessington-street, Dublin.
Clark, Courtney K.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
Clark, G. T. Bombay; and Athenæum Club, London, S.W.
1846. *CLARK, HENRY, M.D. 2 Arundel-gardens, Kensington, London, W.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
Clarke, George. Mosley-street, Manchester.
1872. *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.
1861. *Clarke, J. H. Lark Hill House, Edgeley, Stockport.
1842. *Clarke, Joseph.*

Year of Election.

1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1850. ‡Cleghorn, Hugh, M.D., F.L.S., late Conservator of Forests, Madras. Stravithy, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1861. §Cleland, John, M.D., F.R.S., Professor of Anatomy and Physiology in Queen's College, Galway.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
Clerke, Rev. C. C., D.D., Archdeacon of Oxford and Canon of Christ Church, Oxford. Milton Rectory, Abingdon, Berkshire.
1852. ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1873. §Cliff, John. Halton, Runcorn.
1869. §Clifford, William Kingdon, M.A., Professor of Applied Mathematics and Mechanics in University College. 14 Maryland-road, Harrow-road, London, W.
1865. ‡Clift, John E., C.E. Redditch, Bromsgrove, near Birmingham.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866. §Close, Thomas, F.S.A. St. James's-street, Nottingham.
1873. §Clough, John. Bracken Bank, Keighley, Yorkshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. South Bank, Weston, near Bath.
1851. *Cobbold, John Chevallier, Holywells, Ipswich; and Athenæum Club, London, S.W.
1864. ‡Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Lecturer on Zoology and Comparative Anatomy at the Middlesex Hospital. 42 Harley-street, London, W.
1864. *Cochrane, James Henry. 129 Lower Baggot-street, Dublin.
1854. ‡Cockey, William. 38 Burnbank-gardens, Glasgow.
1861. *Coe, Rev. Charles C., F.R.G.S. Highfield, Bolton.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1853. ‡Colchester, William, F.G.S. Grundesburgh Hall, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1859. *Cole, Henry Warwick, Q.C. Warwick.
1860. ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1861. *Collie, Alexander. 12 Kensington Palace-gardens, London, W.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. 4 Grove-terrace, Belvedere-road, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.

Year of Election.

Collis, Stephen Edward. Listowel, Ireland.
1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. §Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
Colthurst, John. Clifton, Bristol.
*COMPTON, The Rev. Lord ALWYN. Castle Ashby, Northamptonshire.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Conual, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Hope House, College Park East, Belfast.
1864. *Conwell, Eugene Alfred, M.R.I.A. Trim, Co. Meath, Ireland.
1863. ‡COOKE, EDWARD WILLIAM, R.A., F.R.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868. ‡Cooke, Rev. George H. The Parsonage, Thorpe, Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish Road, Birkenhead.
1868. §COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. Telegraph Office, Lothbury, London, E.C.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, W.; and Rainthorpe Hall, Long Stratton.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1862. *Cookson, Rev. H. W., D.D. St. Peter's College Lodge, Cambridge.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin. Mile Ash, Derby.
1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1868. ‡Cooper, W. J. 28 Duke-street, Westminster, S.W.
1846. ‡Cooper, William White. 19 Berkeley-square, London, W.
1871. ‡Copeland, Ralph, Ph.D. Parsonstown, Ireland.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.
1842. *Corbet, Richard. Bayshill Lawn, Cheltenham.
1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
1870. *CORFIELD, W. H., M.A., M.B., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cormack, John Rose, M.D., F.R.S.E. 5 Bedford-square, London, W.C.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazennose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Grahamstown.
1864. §COTTON, General FREDERICK C. Athenæum Club, Pall Mall, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
*Cotton, Rev. William Charles, M.A. Vicarage, Frodsham, Cheshire.
1865. ‡Courtald, Samuel, F.R.A.S. 76 Lancaster-gate, London; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.

Year of
Election.

1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William. Hawthorn House, Horsham.
1873. *Cowans, John. Cranford, Middlesex.
Cowie, Rev. Benjamin Morgan, M.A. 42 Upper Harley-street, Cavendish-square, London, W.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Clement Park, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
Cox, Robert. 25 Rutland-street, Edinburgh.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 50 Newhall-street, Birmingham.
1871. ‡Cox, William J. 2 Vanburgh-place, Leith.
1854. ‡CRACE-CALVERT, FREDERICK, Ph.D., F.R.S., F.C.S., Honorary Professor of Chemistry to the Manchester Royal Institution. Royal Institution, Manchester.
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1859. ‡Craig, S. The Wallands, Lewes, Sussex.
1857. ‡Crampton, Rev. Josiah., M.R.I.A. The Rectory, Florence-court, Co. Fermanagh, Ireland.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1871. *Crawford, William Caldwell. Eagle Foundry, Port Dundas, Glasgow.
1871. §Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cyfarthfa Castle, Merthyr Tydvil.
Creyke, The Venerable Archdeacon. Beeford Rectory, Driffield.
1865. ‡Crocker, Edwin, F.C.S. 76 Hungerford-road, Holloway, London, N.
1858. ‡Crofts, John. Hillary-place, Leeds.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1855. ‡Crompton, Charles, M.A. 22 Hyde Park-square, London, W.
*CROMPTON, Rev. JOSEPH, M.A. Bracondale, Norwich.
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
1870. §Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 20 Mornington-road, Regent's Park, London, N.W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 5 Alexander-drive, Prince's Park, Liverpool.
1870. *Crosfield, William, jun. 5 Alexander-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §CROSSKEY, Rev. H. W., F.G.S. 28 George-street, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bermerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1865. ‡Crotch, George Robert. 19 Trumpington-street, Cambridge.
1861. §Crowley, Henry. Smedley New Hall, Cheetham, Manchester.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.

Year of Election.

1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. §Crust, Walter. Hall-street, Spalding.
Culley, Robert. Bank of Ireland, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1861. *Cunliffe, Edward Thomas. The Elms, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Handforth, Manchester.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, Professor ROBERT O., M.D. Queen's College, Belfast.
1855. ‡Cunningham, William A. Manchester and Liverpool District Bank, Manchester.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.S.A., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡Curtis, Professor Arthur Hill, LL.D. 6 Trinity College, Dublin.
1866. ‡*Cusins, Rev. F. L.*
1834. *Cuthbert, John Richmond. 40 Chapel-street, Liverpool.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡*Dallinger, Rev. W. H.*
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
1859. ‡Dalrymple, Colonel. Troup, Scotland.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡Danby, T. W. Downing Collge, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1873. §Danchill, F. H. Vale Hall, Horwich, Bolton, Lancashire.
1849. *Danson, Joseph, F.C.S. 97 City-road, Hulme, Manchester.
1859. ‡Darbishire, Charles James. Rivington, near Chorley, Lancashire.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1852. ‡*Darby, Rev. Jonathan L.*
DARWIN, CHARLES R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E., and M.R.I.A. Down, near Bromley, Kent.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1872. §Davenport, John T. 64 Marine Parade, Brighton.
Davey, Richard, F.G.S. Redruth, Cornwall.
1870. ‡Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.
1871. §Davidson, David. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡DAVIDSON, THOMAS, F.R.S., F.G.S. 8 Denmark-terrace, Brighton.
1868. ‡*Davie, Rev. W. C.*
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1863. ‡Davies, Griffith. 17 Cloudesley-street, Islington, London, N.
Davies, John Birt, M.D. The Laurels, Edgbaston, Birmingham.
1842. Davies-Colley, Dr. Thomas. 40 Whitefriars, Chester.
1873. *Davis, Alfred. Sun Foundry, Leeds.

Year of Election.

1870. *Davis, A. S. Roundhay Vicarage, near Leeds.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1873. §Davis, James W. Albert House, Greetland, near Halifax.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, Westbury by Bristol.
1859. ‡DAVIS, J. BARNARD, M.D., F.R.S., F.S.A. Shelton, Hanley, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1873. §Davis, William Samuel. 1 Cambridge-villas, Derby.
1864. §Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
Dawes, John Samuel, F.G.S. Lappel Lodge, Quinton, near Birmingham.
1860. *Dawes, John T., jun. Perry Hill House, Quinton, near Birmingham.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A. Birchview, Norman-road, Rusholme, Manchester.
1865. ‡Dawson, George, M.A. Shenstone, Lichfield.
*Dawson, Henry. Shu-le-Crow House, Keswick, Cumberland.
Dawson, John. Barley House, Exeter.
1855. ‡DAWSON, JOHN W., M.A., LL.D., F.R.S., Principal of M'Gill College, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1871. ‡Day, St. John Vincent. 166 Buchanan-street, Glasgow.
1870. §Deacon, G. F. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1870. ‡Deacon, Henry Wade. King's College, London, W.C.
1859. ‡Dean, David. Banchory, Aberdeen.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, D.Sc., B.A., F.G.S. Moseley, Birmingham.
1854. §DEANE, HENRY, F.L.S. Clapham Common, London, S.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. Lecturer on Chemistry at Guy's Hospital, London, S.E.
1854. *DE LA RUE, WARREN, D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1870. ‡De Meschin, Thomas, M.A., LL.D. 3 Middle Temple-lane, Temple, E.C.
Denchar, John. Morningside, Edinburgh.
*Dent, Joseph. Ribston Hall, Wetherby.
Dent, William Yerbury. Royal Arsenal, Woolwich, S.E.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1856. *DERBY, The Right Hon. the Earl of, LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.
1870. ‡Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
DE TABLEY, GEORGE, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡DEVON, The Right Hon. the Earl of. Powderham Castle, near Exeter.

Year of Election.

*DEVONSHIRE, WILLIAM, Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. §DEWAR, JAMES, F.R.S.E. Chemical Laboratory, The University, Edinburgh.
1872. ‡Dewick, Rev. E. S. The College, Eastbourne, Sussex.
1873. *Dew-Smith, A. G. Rushett House, Thames Ditton.
1858. ‡Dibb, Thomas Townend. Little Woodhouse, Leeds.
1870. ‡*Dickens, Colonel C. H.*
1852. ‡DICKIE, GEORGE, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1861. *Dickinson, William Leeson 1 St. James's-street, Manchester.
1867. §DICKSON, ALEXANDER, M.D., Professor of Botany in the University of Glasgow. 11 Royal-circus, Edinburgh.
1868. ‡Dickson, J. Thompson. 33 Harley-street, London, W.
1863. *Dickson, William, F.S.A., Clerk of the Peace for Northumberland. Alnwick, Northumberland.
1862. *DILKE, Sir CHARLES WENTWORTH, Bart., M.P. 76 Sloane-street, London, S.W.
1848. ‡DILLWYN, LEWIS LLEWELYN, M.P., F.L.S., F.G.S. Parkwern, near Swansea.
1872. §Dines, George. Grosvenor-road, London, S.W.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1837. DIRCKS, HENRY, C.E., LL.D., F.C.S. 48 Charing-cross, London, S.W.
1868. ‡DITTMAR, W. The University, Edinburgh.
1853. ‡Dixon, Edward, M.Inst.C.E. Wilton House, Southampton.
1865. ‡Dixon, L. Hooton, Cheshire.
1861. ‡DIXON, W. HEPWORTH, F.S.A., F.R.G.S. 6 St. James's-terrace, London, N.W.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. *Dobbs, Archibald Edward, M.A. Richmond-road, Ealing, W.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
Dockray, Benjamin.
1870. *Dodd, John. 9 Canning-place, Liverpool.
1857. ‡Dodds, Thomas W., C.E. Rotherham.
*Dodsworth, Benjamin. Burton Croft, York.
*Dodsworth, George. The Mount, York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1873. §Donham, Thomas. Huddersfield.
*Donisthorpe, George Edmund. Belvedere, Harrogate, Yorkshire.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1871. ‡DONKIN, ARTHUR SCOTT, M.D., Lecturer on Forensic Medicine at Durham University. Sunderland.
1861. ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *DONNELLY, WILLIAM, C.B., Registrar-General for Ireland. Charlemont House, Dublin.
1857. ‡Donovan, M., M.R.I.A. Clare-street, Dublin.

Year of Election.

1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. **Doughty, C. Montagu.*
1855. ‡Dove, Hector. Rose Cottage, Trinity, near Edinburgh.
1870. ‡Dowie, J. M. Walstones, West Kirby, Liverpool.
Downall, Rev. John. Okehampton, Devon.
1857. ‡Downing, S., LL.D., Professor of Civil Engineering in the University of Dublin. Dublin.
1872. *Dowson, Edward, M.D. 117 Park-street, London, W.
1865. *Dowson, E. Theodore. Geldestone, near Beccles, Suffolk.
1869. ‡*Drake, Francis, F.G.S.*
Drennan, William, M.R.I.A. 35 North Cumberland-street, Dublin.
1868. §Dresser, Henry E., F.Z.S. 6 Tenterden-street, Hanover-square, W.
1873. §Drew, Frederick. Surbiton.
1869. §Drew, Joseph, LL.D., F.G.S., F.R.S.C., F.R.S.L. Weymouth.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
1872. *Druce, Frederick. 27 Oriental-place, Brighton.
Drummond, H. Home, F.R.S.E. Blair Drummond, Stirling.
1858. ‡Drummond, James. Greenock.
1859. ‡Drummond, Robert. 17 Stratton-street, London, W.
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1863. ‡Dryden, James. South Benwell, Northumberland.
1870. §Drysdale. J. J., M.D. 36A Rodney-street, Liverpool.
1856. *Ducie, Henry John Reynolds Moreton, Earl of, F.R.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 5 Cook-street, Liverpool.
1867. *Duff, Mounstuart Ephinstone Grant-, LL.B., M.P. 4 Queen's Gate-gardens, South Kensington, London, W.; and Eden, near Banff, Scotland.
1852. ‡Dufferin, The Right Hon. Lord. Highgate, London, N.; and Clandeboye, Belfast.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
1867. ‡Duncan, Peter Martin, M.D., F.R.S., F.G.S., Professor of Geology in King's College, London. 40 Blessington-road, Lee, S.E.
Dunlop, Alexander. Clober, Milngavie, near Glasgow.
1853. *Dunlop, William Henry. Annan-hill, Kilmarnock, Ayrshire.
1865. §Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1862. §Dunn, Robert, F.R.C.S. 31 Norfolk-street, Strand, London W.C.
Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall, York.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1852. ‡Dunville, William. Richmond Lodge, Belfast.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. §Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.

Year of Election.

1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1864. ‡*Earle, Rev. A.*
*EARNSHAW, Rev. SAMUEL, M.A. 14 Broomfield, Sheffield.
1871. *Easton, Edward. 23 Duke-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham.
Eaton, Rev. George, M.A. The Pole, Northwich.
1870. §Eaton, Richard. North Mymms Park, Hatfield, Herts.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1867. ‡Eckersley, James. Leith Walk, Edinburgh.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Blandford, Dorset.
1870. *Eddison, Dr. John Edwin. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
*EDGEWORTH, MICHAEL P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.
1855. ‡Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 8 York-place, Northam, Southampton.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. §Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867. ‡Edward, James. Balruddery, Dundee.
Edwards, John. Halifax.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1867. ‡Edwards, William. 70 Princes-street, Dundee.
*EGERTON, Sir PHILIP DE MALPAS GREY, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1873. §Elcock, Charles. 71 Market-street, Manchester.
1855. ‡Elder, David. 19 Paterson-street, Glasgow.
1858. ‡Elder, John. Elm Park, Govan-road, Glasgow.
1868. §Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst, St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1855. §Elliot, Robert, F.B.S.E. Wolfelee, Hawick, N.B.
1861. *ELLIOT, Sir WALTER, K.C.S.I., F.L.S. Wolfelee, Hawick, N.B.
1864. ‡Elliott, E. B. Washington, United States.
1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
Elliott, John Fogg. Elvet Hill, Durham.
1864. *ELLIS, ALEXANDER JOHN, B.A., F.R.S. 25 Argyll-road, Kensington, London, W.
1859. ‡ELLIS, HENRY S., F.R.A.S. Fair Park, Exeter.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. §Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1869. ‡Ellis, William Horton. Pennsylvania, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
Eltoft, William. Care of J. Thompson, Esq., 30 New Cannon-street, Manchester.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.

Year of Election.

1871. ‡Engelson, T. 11 Portland-terrace, Regent's Park, London, N.W.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Stratton, Cornwall.
ENNISKILLEN, WILLIAM WILLOUGHBY, Earl of, D.C.L., F.R.S., M.R.I.A., F.G.S. 26 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1869. ‡Ensor, Thomas. St. Leonards, Exeter.
1869. *Enys, John Davis. Canterbury, New Zealand. (Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.)
1844. ‡Erichsen, John Eric, Professor of Clinical Surgery in University College, London. 9 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡ETHERIDGE, ROBERT, F.R.S.E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.
1855. *Euing, William. 209 West George-street, Glasgow.
1870. *Evans, Arthur John. Nash Mills, Hemel Hempstead.
1865. *EVANS, Rev. CHARLES, M.A. Solihull Rector, Birmingham.
1872. *Evans, Frederick J., C.E. Clayponds, Brentford, W.
1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, S.W.
1861. *EVANS, JOHN, F.R.S., F.S.A., Sec. G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempsted.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Highgate, near Birmingham.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.
Evanson, R. T., M.D. Holme Hurst, Torquay.
1871. §Eve, H. W. Wellington College, Wokingham, Berkshire.
1868. *EVERETT, J. D., D.C.L., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.
1863. *Everitt, George Allen, K.L., K.H., F.R.G.S. Knowle Hall, Warwickshire.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warren's, near Lyndhurst, Hants.
1866. ‡EYRE, Major-General Sir VINCENT, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1842. Fairbairn, Thomas. Manchester.
*FAIRBAIRN, Sir WILLIAM, Bart., C.E., LL.D., F.R.S., F.G.S., F.R.G.S. Manchester.
1865. ‡Fairley, Thomas. Chapel Allerton, Leeds.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1873. §Farakerley, Miss. The Castle, Denbigh.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1861. ‡FARR, WILLIAM, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Registry Office. Southlands, Bickley, Kent.

Year of Election.

1866. *Farrar, Rev. Frederick William, D.D., F.R.S. Marlborough College, Wilts.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulconer, R. S. Fairlawn, Clarence-road, Clapham Park, London.
1869. *Faulding, Joseph. 340 Euston-road, London, N.W.
1869. ‡Faulding, W. F. Didsbury College, Manchester.
1859. *Fawcett, Henry, M.P., Professor of Political Economy in the University of Cambridge. 42 Bessborough-gardens, Pimlico, London, S.W.; and 8 Trumpington-street, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1833. Fearon, John Peter. Cuckfield, Sussex.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverston, Lancashire.
1864. §Fellowes, Frank P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square, and Keswick, near Belfast.
1855. ‡Ferguson, James. Gas Coal Works, Lesmahago, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. §Ferguson, John. The College, Glasgow.
1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Samuel. 20 North Great George-street, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *Fernie, John. Bonchurch, Isle of Wight.
1862. ‡Ferrers, Rev. N. M., M.A. Caius College, Cambridge.
1873. §Ferrier, David, M.D. 23 Somerset-street, Portman-square, W.
1868. ‡Field, Edward. Norwich.
Field, Edwin W. 36 Lincoln's-Inn-fields, London, W.C.
1869. *Field, Rogers. 5 Cannon-row, Westminster, S.W.
Fielding, G. H., M.D.
1864. ‡Finch, Frederick George, B.A., F.G.S. 21 Crooms-hill, Greenwich, S.E.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1859. ‡Findlay, Alexander George, F.R.G.S. 53 Fleet-street, London, E.C.; Dulwich Wood Park, Surrey.
1863. ‡Finney, Samuel. Sheriff-hill Hall, Newcastle-upon-Tyne.
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *Fischer, William L. F., M.A., LL.D., F.R.S., Professor of Mathematics in the University of St. Andrews, Scotland.
1858. ‡Fishbourne, Captain E. G., R.N. 6 Welamere-terrace, Paddington, London, W.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlston Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W., F.C.S. Crossbeck, Ilkley.
1871. §Fitch, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1857. ‡Fitzgerald, The Right Hon. Lord Otho. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
Fitzwilliam, Hon. George Wentworth, F.R.G.S. 19 Grosvenor-square, London, S.W.; and Wentworth House, Rotherham.

Year of Election.

1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 121 Hagley-road, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
Fleming, John G., M.D. 155 Bath-street, Glasgow.
*FLEMING, WILLIAM, M.D. Rowton Grange, near Chester.
1867. §Fletcher, Alfred E. 21 Overton-street, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1853. ‡FLETCHER, ISAAC, F.R.S., F.G.S., F.R.A.S. Tarn Bank, Workington.
1869. §FLETCHER, LAVINGTON E., C.E. 41 Corporation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡FLOWER, WILLIAM HENRY, F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1867. ‡Foggie, William. Woodville, Maryfield, Dundee.
1854. *FORBES, DAVID, F.R.S., F.G.S., F.C.S. 11 York-place, Portman-square, London, W.
1873. *Forbes, Professor George, B.A., F.R.S.E. Anderson's University, Glasgow.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
1855. ‡Forbes, Rev. John, D.D. 150 West Regent-street, Glasgow.
Ford, H. R. Morecombe Lodge, Yealand Conyers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
*Forrest, William Hutton. The Terrace, Stirling.
1867. ‡Forster, Anthony. Newsham Grange, Winston, Darlington.
1849. *Forster, Thomas Emerson. 7 Ellison-place, Newcastle-upon-Tyne.
*Forster, William. Ballynure, Clones, Ireland.
1858. *FORSTER, Right Hon. WILLIAM EDWARD, M.P. Wharfeside, Burley-in-Wharfedale, Leeds.
1871. ‡Forsyth, William F. Denham Green, Trinity, Edinburgh.
1854. *Fort, Richard. 24 Queen's-gate-gardens, London, W.; and Read Hall, Whalley, Lancashire.
1870. ‡Forwood, William B. Hopeton House, Seaforth, Liverpool.
1865. ‡Foster, Balthazar W., M.D. 4 Old-square, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.G.S. Truro, Cornwall.
1857. *FOSTER, GEORGE C., B.A., F.R.S., F.C.S., Professor of Experimental Physics in University College, London, W.C. 12 Hilldrop-road, London, N.
*Foster, Rev. John, M.A. The Oaks Vicarage, Loughborough.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1859. *FOSTER, MICHAEL, M.A., M.D., F.R.S., F.L.S., F.C.S. (GENERAL SECRETARY.) Trinity College, and Great Shelford, near Cambridge.
1859. §FOSTER, PETER LE NEVE, M.A. Society of Arts, Adelphi, London, W.C.
1873. §Foster, Peter Le Neve, jun. Mortara, Italy.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.
1873. *Foster, William. Harrowins House, Queensbury, Yorkshire.
1842. Fothergill, Benjamin. 10 The Grove, Boltons, West Brompton, London.
1870. ‡Foulger, Edward. 55 Kirkdale-road, Liverpool.
1866. §Fowler, George. Basford Hall, near Nottingham.

Year of Election.

1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1856. ‡Fowler, Rev. Hugh, M.A. College-gardens, Gloucester.
1870. *Fowler, Robert Nicholas, M.A., F.R.G.S. 36 Cavendish-square, London, W.
Fox, Alfred. Penjerrick, Falmouth.
1868. ‡Fox, Colonel A. H. LANE, F.G.S., F.S.A. 10 Upper Phillimore-gardens, Kensington, London, S.W.
1842. *Fox, Charles. Trebah, Falmouth.
*Fox, Rev. Edward, M.A. The Vicarage, Romford, Essex.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
FOX, ROBERT WERE, F.R.S. Falmouth.
1866. *Francis, G. B. 71 Stoke Newington-road, London, N.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster-gate, London. W.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
Franks, Rev. J. C., M.A. Whittlesea, near Peterborough.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. §FARSER, THOMAS R., M.D., F.R.S.E. 3 Grosvenor-street, Edinburgh.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1871. ‡*Freeman.*
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
Frere, George Edward, F.R.S. Royden Hall, Diss, Norfolk.
1869. ‡FRERE, Sir H. BARTLE E., G.C.S.I., K.C.B., F.R.G.S. 22 Prince's-gardens, London.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
Fripp, George, D., M.D.
1857. *Frith, Richard Hastings, C.E., M.R.I.A., F.R.G.S.I. 48 Summer-hill, Dublin.
1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse-hill, London, S.W.
1860. *FROUDE, WILLIAM, C.E., F.R.S. Chelston Cross, Torquay.
Fry, Francis. Cotham, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
Fry, Robert. Tockington, Gloucestershire.
1863. ‡Fryar, Mark. Eaton Moor Colliery, Newcastle-on-Tyne.
1872. *Fuller, Rev. A. Ichenor, Chichester.
1873. §Fuller, Claude S., R.N. 44 Holland-road, Kensington, W.
1859. ‡FULLER, FREDERICK, M.A., Professor of Mathematics in University and King's College, Aberdeen.
1869. ‡FULLER, GEORGE, C.E., Professor of Engineering in University College, London. Argyll-road, Kensington, London, W.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.

Year of Election.

1857. ‡Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Handsworth Grange, near Sheffield.
1850. ‡Gairdner, Professor W. F., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
GALBRAITH, Rev. J. A., M.R.I.A. Trinity College, Dublin.
1867. ‡Gale, James M. 33 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1860. *GALTON, Captain DOUGLAS, C.B., R.E., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 13 Margaret-street, Cavendish-square, London, W.
1870. §Gamble, D. St. Helens, Lancashire.
1870. *Gamble, John G. Albion House, Rottingdean, Brighton.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S., F.R.S.E. Owens College, Manchester.
1862 §GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. §Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1873. §Garnham, John. 123 Bunhill-row, E.C.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Mayfield-road, Aigburth, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1846. §GASSIOT, JOHN PETER, D.C.L., LL.D., F.R.S., F.C.S. Clapham Common, London, S.W.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinstead, Sussex.
1873. §Geach, R. G. Cragg Wood, Rawdon, Yorkshire.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M.A., Professor of Greek, King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. §GEIKIE, ARCHIBALD, F.R.S., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh; and Ramsay Lodge, Edinburgh.
1871. §Geikie, James, F.R.S.E. 16 Duncan-terrace, Newington, Edinburgh.
1855. ‡Gemmell, Andrew. 38 Queen-street, Glasgow.
1854. §Gerard, Henry. 8A Rumford-place, Liverpool.
1870. ‡Gerstl, R. University College, London, W.C.
1870. *Gervis, Walter S., M.D. Ashburton, Devon.
1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
1863. *GIBB, Sir GEORGE DUNCAN, Bart., M.D., M.A., LL.D., F.G.S. 1 Bryanston-street, London, W.; and Falkland, Fife.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. ‡Gibson, Alexander. 19 Albany-street, Edinburgh.
1868. ‡Gibson, C. M. Bethel-street, Norwich.
*Gibson, George Stacey. Saffron Walden, Essex.
1852. ‡Gibson, James. 35 Mountjoy-square, Dublin.
1870. ‡Gibson, R. E. Sankey Mills, Earlestown, near Newton-le-Willows.
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 19 Parkfield-road, Princes Park, Liverpool.

Year of Election.

1867. ‡Gibson, W. L., M.D. Tay-street, Dundee.
1842. GILBERT, JOSEPH HENRY, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *Gill, David, jun. The Observatory, Aberdeen.
1868. ‡Gill, Joseph. Palermo, Sicily (care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.).
1864. ‡GILL, THOMAS. 4 Sydney-place, Bath.
1861. *Gilroy, George. Hindley Hall, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1867. §GINSBURG, Rev. C. D., D.C.L., LL.D. Binfield, Bracknell, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Cliftonville, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1861. *Gladstone, Murray. Manchester.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., B.A., F.R.A.S. Trinity College, Cambridge.
1853. ‡Gleadon, Thomas Ward. Moira-buildings, Hull.
1870. §Glen, David Corse. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London, W.C.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
Glover, Thomas. Becley Old Hall, Rowsley, Bakewell.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. §GODDARD, RICHARD. 29 Marlborough-road, Manningham-lane, Bradford.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1846. ‡GODWIN-AUSTEN, ROBERT A. C., B.A., F.R.S., F.G.S. Chilworth Manor, Guildford.
GOLDSMID, Sir FRANCIS HENRY, Bart., M.P. St. John's Lodge, Regent's Park, London, N.W.
1873. §Goldthorp, Miss R. F. C. Cleckheaton, Bradford.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870. ‡Goodison, George William, C.E. Gateacre, Liverpool.
1842. *GOODMAN, JOHN, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Westhall Vicarage, Wangford.
1871. §Gordon, Joseph. Poynter's-row, Totteridge, Whetstone, London, N.
1840. ‡Gordon, Lewis D. B. Totteridge, Whetstone, N.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870. ‡Gossage, William. Winwood, Woolton, Liverpool.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.I.C.E. Parkfield-road, Manningham, Bradford.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, George S., Viscount. Rathronan House, Clonmel.
1868. §Gould, Rev. George. Unthank-road, Norwich.
GOULD, JOHN, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.

Year of Election.

1854. ‡*Gourlay, Daniel De la C., M.D.*
1873. §Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford.
1867. ‡Gourley, Henry (Engineer). Dundee.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Manville-crescent, Bradford.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *Graham, Cyril, F.L.S., F.R.G.S. 9 Cleveland-row, St. James's, London, S.W.
Graham, Lieutenant David. Mecklewood, Stirlingshire.
1852. *Grainger, Rev. John, D.D. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1871. ‡Grant, Sir Alexander, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1870. §Grant, Colonel J. A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 7 Park-square West, London, N.W.
1859. ‡Grant, Hon. James. Cluny Cottage, Forres.
1855. *Grant, Robert, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡Grantham, Richard B., C.E., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
*Graves, Rev. Richard Hastings, D.D. Brigown Glebe House, Michelstown, Co. Cork.
1864. *Gray, Rev. Charles. The Vicarage, East Retford.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.
1857. ‡Gray, Sir John, M.D. Rathgar, Dublin.
*Gray, John Edward, Ph.D., F.R.S., Keeper of the Zoological Collections of the British Museum. British Museum, London, W.C.
1864. ‡Gray, Jonathan. Summerhill House, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. §Gray, J. Macfarlane. 10 York-grove, Queen's-road, Peckham, London, S.E.
*Gray, William, F.G.S. Gray's-court, Minster Yard, York.
1873. §Gray, William, Hon. Sec. Belfast Naturalists' Field Club. Belfast.
1861. *Gray, Lieut.-Colonel William. 26 Prince's-gardens, London, S.W.
1854. *Grazebrook, Henry. Clent Grove, near Stourbridge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 32 Friar-gate, Derby.
1873. §Greaves, James H., C.E. Albert-buildings, Queen Victoria-street, London, E.C.
1869. §*Greaves, William.*
1872. §Greaves, William. 2 Raymond-buildings, Gray's Inn, London, W.C.
1872. *Grece, Clair J. Redhill, Surrey.
Green, Rev. Henry, M.A. Heathfield, Knutsford, Cheshire.
*Greenaway, Edward. 91 Lansdowne-road, Notting Hill, London, W.
1858. *Greenhalgh, Thomas. Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1862. *Greenwood, Henry. 32 Castle-street, and The Woodlands, Liverpool.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.

Year of Election.

1861. ‡Gregson, Samuel Leigh. Aigburth-road, Liverpool.
*Greswell, Rev. Richard, B.D., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
1869. ‡Grey, Sir George, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1866. ‡Grey, Rev. William Hewett C. North Sherwood, Nottingham.
1863. ‡Grey, W. S. Norton, Stockton-on-Tees.
1871. *Grierson, Samuel. Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1870. ‡Grieve, John, M.D. 21 Lynedock-street, Glasgow.
*Griffin, John Joseph, F.C.S. 22 Garrick-street, London, W.C.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *Griffith, George, M.A., F.C.S. (Assistant General Secretary.) Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1868. ‡Griffith, Rev. John, M.A., D.C.L. Findon Rectory, Worthing, Sussex.
1870. ‡Griffith, N. R. The Coppa, Mold, North Wales.
1870. ‡Griffith, Rev. Professor. Bowden, Cheshire.
*Griffith, Sir Richard John, Bart., LL.D., F.R.S.E., M.R.I.A., F.G.S. 2 Fitzwilliam-place, Dublin.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
Griffiths, Rev. John, M.A. Wadham College, Oxford.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1864. ‡Groom-Napier, Charles Ottley, F.G.S. 20 Maryland-road, Harrow-road, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. The Athenæum Club, Pall Mall, London, S.W.
Grove, The Hon. Sir William Robert, M.A., Ph.D., F.R.S. 115 Harley-street, W.
1863. *Groves, Thomas B., F.C.S. 80 St. Mary's-street, Weymouth.
1869. ‡Grubb, Howard, F.R.A.S. 40 Leinster-square, Rathmines, Dublin.
1857. ‡Grubb, Thomas, F.R.S., M.R.I.A. 141 Leinster-road, Dublin.
1872. ‡Grüneisen, Charles Lewis, F.R.G.S. 16 Surrey-street, Strand, London, W.C.
Guest, Edwin, LL.D., M.A., F.R.S., F.L.S., F.R.A.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford Park, Oxfordshire.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *Guise, Sir William Vernon, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, Rev. John, M.A., F.G.S. Irstedd Rectory, Norwich.
1866. ‡Günther, Albert C. L. G., M.D., F.R.S. British Museum, London, W.C.
1868. *Gurney, John. Sprouston Hall, Norwich.
1860. *Gurney, Samuel, F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Blake-street, York.
1859. ‡Guthrie, Frederick, F.R.S. Professor of Physics in the Royal School of Mines. 24 Stanley-crescent, Notting Hill, London, N.W.
1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.

Year of Election.

1870. ‡*Guyton, Joseph.*
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. §Hackney, William. Walter's-road, Swansea.
1866. *Hadden, Frederick J. 3 Park-terrace, Nottingham.
1866. ‡Haddon, Henry. Lenton Field, Nottingham.
Haden, G. N. Trowbridge, Wiltshire.
1865. ‡*Haden, W. H.*
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.
1870. ‡Halhead, W. B. 7 Parkfield-road, Liverpool.
HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
Hall, John Robert. Sutton, Surrey.
1872. *Hall, Captain Marshall. New University Club, St. James's, London, S.W.
*Hall, Thomas B. Australia (care of J. P. Hall, Esq., Crane House, Great Yarmouth).
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. §Hall, Walter. 10 Pier-road, Erith.
1873. §Hallett, T. G. P., M.A. Bristol.
1868. *HALLETT, WILLIAM HENRY, F.L.S. The Manor House, Kemp Town, Brighton.
1861. ‡Halliday, James. Whalley Cottage, Whalley Range, Manchester.
1857. ‡Halpin, George, C.E. Rathgar, near Dublin.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Barrow-on-Soar, near Loughborough.
1866. §HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1857. ‡Hamilton, Charles W. 40 Dominick-street, Dublin.
1865. §Hamilton, Gilbert. Leicester House, Kenilworth-road, Leamington.
HAMILTON, The Very Rev. HENRY PARR, Dean of Salisbury, M.A., F.R.S. L. & E., F.G.S., F.R.A.S. Salisbury.
1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.
1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1871. §Hanbury, Daniel. Clapham Common, London, S.W.
1863. ‡HANCOCK, ALBANY, F.L.S. 4 St. Mary's-terrace, Newcastle-upon-Tyne.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John. Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, N.
1857. ‡Hancock, William J. 74 Lower Gardiner-street, Dublin.
1847. ‡HANCOCK, W. NELSON, LL.D. 74 Lower Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
Handyside, P. D., M.D., F.R.S.E. 11 Hope-street, Edinburgh.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.

Year of Election.

*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. 3 Norham-gardens, Oxford.
Harcourt, Rev. C. G. Vernon, M.A. Rothbury, Northumberland.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Hill's Court, Exeter.
1869. ‡Harding, William D. Islington Lodge, Kings Lynn, Norfolk.
1872. §Hardwicke, Mrs. 192 Piccadilly, London, W.
1864. §Hardwicke, Robert, F.L.S. 192 Piccadilly, London, W.
*HARE, CHARLES JOHN, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
Harford, Summers. Haverfordwest.
1858. ‡Hargrave, James. Burley, near Leeds.
1853. §HARKNESS, ROBERT, F.R.S. L. & E., F.G.S., Professor of Geology in Queen's College, Cork.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S., Professor of Medical Jurisprudence in University College, London. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. Mill Hill School, Middlesex; and The Hawthorns, Church End, Finchley, N.
1861. ‡Harman, H. W., C.E. 16 Booth-street, Manchester.
1868. *HARMER, F. W., F.G.S. Heigham Grove, Norwich.
1872. §Harpley, Rev. William, M.A., F.C.P.S. Clayhanger Rectory, Tiverton.
*Harris, Alfred. Oxton Hall, Tadcaster.
*Harris, Alfred, jun. Lunefield, Kirkby-Lonsdale, Westmoreland.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
*Harris, Henry. Longwood, near Bingley, viâ Leeds.
1863. ‡Harris, T. W. Grange, Middlesborough-on-Tees.
1873. §Harris, W. W. Oak-villas, Bradford.
1860. †Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. §Harrison, George. Barnsley, Yorkshire.
1873. §Harrison, George, Ph.D., F.L.S., F.C.S. Glossop-road, Sheffield.
1858. *HARRISON, JAMES PARK, M.A. Cintra Park Villa, Upper Norwood, S.E.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1853. *Harrison, William, F.S.A., F.G.S. Samlesbury Hall, near Preston, Lancashire.
1849. ‡HARROWBY, The Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, S.W.; and Sandon Hall, Lichfield.
1859. *Hart, Charles. Harbourne Hall, Birmingham.
1861. *Harter, J. Collier. Chapel Walks, Manchester.
1842. *Harter, William. Hope Hall, Manchester.
1856. ‡Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Cheltenham.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel. King's College, London, W.C.
1854. §HARTNUP, JOHN, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.

Year of Election.

*Harvey, Joseph Charles. Knockrea House, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-moors.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1837. ‡Hastings, W. Huddersfield.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
1857. ‡Haughton, Rev. Samuel, M.D., M.A., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
*Haughton, William. 28 City Quay, Dublin.
Hawkins, John Heywood, M.A., F.R.S., F.G.S. Bignor Park, Petworth, Sussex.
1872. *Hawkshaw, Henry Paul. 20 King-street, St. James's, London, W.
*Hawkshaw, Sir John, F.R.S., F.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., F.G.S. 25 Cornwall-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. §Hawksley, Thomas, C.E., F.G.S. 30 Great George-street, London, S.W.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1861. *Hay, Vice-Admiral the Right Hon. Sir John C. D., Bart., C.B., M.P., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1873. *Hayes, Rev. Wm. A., B.A. Bramley, Leeds.
1869. ‡Hayward, J. High-street, Exeter.
1858. *Hayward, Robert Baldwin, M.A. The Park, Harrow-on-the-hill.
1851. §Head, Jeremiah. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.
1861. *Heald, James. Parr's Wood, Didsbury, near Manchester.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1872. §Healey, C. E. H. Chadwyck. 8 Albert-mansions, Victoria-street, London, S.W.
1871. §Healey, George. Matson's, Windermere.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1865. ‡Hearder, William. Victoria Parade, Torquay.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §Heathfield, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.
1865. ‡Heaton, Harry. Warstone, Birmingham.
1858. *Heaton, John Deakin, M.D., F.R.C.P. Claremont, Leeds.
1865. ‡Heaton, Ralph. Harborne Lodge, near Birmingham.
1833. ‡Heaviside, Rev. Canon J. W. L., M.A. The Close, Norwich.
1855. ‡Hector, James, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Foster, M.D., Professor of Chemistry in the University of St. Andrew's, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1862. ‡*Helm, George F.*
1857. *Hemans, George William, C.E., M.R.I.A., F.G.S. 1 Westminster-chambers, Victoria-street, London, S.W.

Year of Election.

1867. ‡Henderson, Alexander. Dundee.
1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London.
1873. *Henderson, A. L. 49 King William-street, E.C.
1866. ‡HENDERSON, JAMES, jun. Dundee.
1873. *HENDERSON, W. D. 12 Victoria-street, Belfast.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. 86 St. Stephen's-green, Dublin.
1857. ‡Hennessy, John Pope. Inner Temple, London, E.C.
1873. §Henrici, Olaus M. F. E., Ph.D., Professor of Mathematics in University College, London.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell, M.P. Stratheden House, Hyde Park, London, W.
*HENRY, WILLIAM CHARLES, M.D., F.R.S., F.G.S., F.R.G.S. Haffield, near Ledbury, Herefordshire.
1870. ‡Henty, William. Norfolk-terrace, Brighton.
HENWOOD, WILLIAM JORY, F.R.S., F.G.S. 3 Clarence-place, Penzance.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Sidcup-place, Sidcup, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1871. ‡Hepburn, Thomas H. St. Mary's Cray, Kent.
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
*Herbert, Thomas. The Park, Nottingham.
1852. ‡Herdman, John. 9 Wellington-place, Belfast.
1866. §Herrick, Perry. Bean Manor Park, Loughborough.
1871. *HERSCHEL, Professor ALEXANDER S., B.A., F.R.A.S. College of Science, Newcastle-on-Tyne.
1865. ‡Heslop, Dr. Birmingham.
1863. ‡Heslop, Joseph. Pilgrim-street, Newcastle-on-Tyne.
1873. §Heugh, John. Holmwood, Tunbridge Wells.
1832. ‡Hewitson, William C. Oatlands, Surrey.
Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
*HEYWOOD, JAMES, F.R.S., F.G.S., F.S.A., F.R.G.S. 26 Kensington Palace-gardens, London, W.
1861 *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1864. *HIERN, W. P., M.A. 1 Foxton-villas, Richmond, Surrey.
1854. **Higgin, Edward.*
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
Higginbotham, Samuel. 4 Springfield-court, Queen-street, Glasgow.
1866. ‡Higginbottom, John. Nottingham.
1871. ‡HIGGINS, CLEMENT, B.A., F.C.S. 27 St. John's-park, Upper Holloway, London, N.
1861. ‡*Higgins, George.*
1854. ‡HIGGINS, Rev. HENRY H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Stocks House, Cheetham, Manchester.
1870. ‡Higginson, Alfred. 44 Upper Parliament-street, Liverpool.
1870. ‡HIGHTON, Rev. H. 2 The Cedars, Putney, S.W.
1842. *Higson, Peter, F.G.S., H.M. Inspector of Mines. The Brooklands, Swinton, near Manchester.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.

Year of Election.

Hill, Arthur. Bruce Castle, Tottenham, London, N.
1872. §Hill, Charles. Rockhurst, West Hoathley, East Grinstead.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. §Hill, John, M.Inst.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. §Hill, Lawrence. The Knowe, Greenock.
*HILL, Sir ROWLAND, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.
1864. ‡Hill, William. Combe Hay, Bristol.
1863 ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. §Hills, Graham H., Staff-Commander R.N. 4 Bentley-road, Princes Park, Liverpool.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Mountside, Leeds.
1870. ‡Hinde, G. J. Buenos Ayres.
Hindley, Rev. H. J. Edlington, Lincolnshire.
1852. *HINDMARSH, FREDERICK, F.G.S., F.R.G.S. 4 New Inn, Strand, London, W.C.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. *Hinmers, William. Cleveland House, Birkdale, Southport.
1858. §Hirst, John, jun. Dobcross, near Manchester.
1861. *HIRST, T. ARCHER, Ph.D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E.; and Athenæum Club, Pall Mall, London, S.W.
1856. ‡Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.
1870. ‡Hitchman, William, M.D., LL.D., F.L.S., &c. 29 Erskine-street, Liverpool.
*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1863. §Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green, London, W.
1866. ‡HOCKIN, CHARLES, M.D. 8 Avenue-road, St. John's Wood, London, N.W.
1852. ‡Hodges, John F., M.D., Professor of Agriculture in Queen's College, Belfast. 23 Queen-street, Belfast.
1863. *HODGKIN, THOMAS. Benwell Dene, Newcastle-on-Tyne.
1873. *Hodgson, George. Thornton-road, Bradford.
1873. §Hodgson, James. Oakfield, Manningham, Bradford.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1839. ‡Hodgson, W. B., LL.D., F.R.A.S. 41 Grove-end-road, St. John's Wood, London, N.W.
1865. *HOFMANN, AUGUSTUS WILLIAM, *LL.D, Ph.D., F.R.S., F.C.S.* 10 Dorotheen Strasse, Berlin.
1860. ‡Hogan, Rev. A. R., M.A. Watlington Vicarage, Oxfordshire.
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1856. ‡Holland, Henry. Dumbleton, Evesham.
1858. §Holland, Loton, F.R.G.S. The Gables, Osborne-road, Windsor.
*Holland, Philip H. Burial Acts Office, 13 Great George-street, *Westminster, S.W.*
1865. ‡Holliday, William. New-street, Birmingham.

Year of Election.

*Hollingsworth, John, M.R.C.S. Maidenstone House, Maidenstone-hill, Greenwich, S.E.
1866. *Holmes, Charles. London-road, Derby.
1873. §Holmes, J. R. Southbrook Lodge, Bradford.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
*Hone, Nathaniel, M.R.I.A. Bank of Ireland, Dublin.
1858. ‡Hook, The Very Rev. W. F., D.D., Dean of Chichester. Chichester.
1847. ‡Hooker, Joseph Dalton, C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew.
1865. *Hooper, John P. The Hut, Mitcham Common, Surrey.
1861. §Hooper, William. 7 Pall Mall East, London, S.W.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1869. §Hope, William, V.C. Parsloes, Barking, Essex.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *Hopkinson, John. Woodlea, Beech-lanes, Birmingham.
1871. §Hopkinson, John, F.G.S., F.R.M.S. 8 Lawn-road, Haverstock-hill, London, N.W.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1864. *Horner, Rev. J. J. H. Mills Rectory, Frome.
1858. *Horsfall, Abraham. Manor House, Whitkirks, near Leeds.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 389 High-street, Cheltenham.
Hotham, Rev. Charles, M.A., F.L.S. Roos, Patrington, Yorkshire.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
1859. ‡*Hough, Joseph.*
Houghton, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.G.S. 16 Upper Brook-street, London, W.
Houghton, James. 41 Rodney-street, Liverpool.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1859. ‡Howard, Captain John Henry, R.N. The Deanery, Lichfield.
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡Howell, Rev. Canon Hinds Drayton Rectory, near Norwich.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, Very Rev. J. S., Dean of Chester. Chester.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1867. ‡Hudson, William H. H., M.A. 19 Bennett's-hill, Doctors Commons, London, E.C.; and St. John's College, Cambridge.
1858. *Huggins, William, D.C.L., Oxon. LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse-hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
Hughes, D. Abraham.
1871. *Hughes, George Pringle, J. P. Middleton Hall, Wooler, Northumberland.
1870. ‡Hughes, Lewis. 38 St. Domingo-grove, Liverpool.
1868. §Hughes, T. M'K., M.A., F.G.S. Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.

Year of Election

1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham.
Hull, Arthur H. 18 Norfolk-road, Brighton.
1867. §HULL, EDWARD, M.A., F.R.S., F.G.S. Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hull, William Darley. Stenton Lodge, Tunbridge Wells.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡HUME, Rev. ABRAHAM, D.C.L., LL.D., F.S.A. All Soul's Vicarage, Rupert-lane, Liverpool.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. The Leys, Cambridge.
1863. *HUNT, AUGUSTUS H., M.A., Ph.D. Birtley House, near Chester-le-Street.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1840. ‡HUNT, ROBERT, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburgh-street, London, W.C.
1855. *Hunter, Thomas O. 13 William-street, Greenock.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1869. §Hurst, George. Bedford.
1861. *Hurst, Wm. John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. Coney-street, York.
1868. *Hutchison, Robert. Carlowrie, Kirkliston, N.B.
1863. ‡HUTT, The Right Hon. Sir W., K.C.B. Gibside, Gateshead.
Hutton, Crompton. Putney-park, Surrey, S.W.
1864. *Hutton, Darnton. (Care of Arthur Lupton, Esq., Headingley, near Leeds.)
Hutton, Henry. Edenfield, Dundrum, Co. Dublin.
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
1861. *Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1871. *Hyett, Francis A. 13 Hereford-square, Old Brompton, London, S.W.
Hyett, William Henry, F.R.S. Painswick, near Stroud, Gloucestershire.
1847. ‡Hyndman, George C. 5 Howard-street, Belfast.

Ihne, William, Ph.D. Heidelberg.
1873. §Ikin, T. J. 19 Park-place, Leeds.
1861. ‡Iles, Rev J. H. Rectory, Wolverhampton.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice General of Scotland. Edinburgh.
1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Regius Professor of Greek. Trinity College, Dublin.
1854. *INMAN, THOMAS, M.D. 8 Vyvyan-terrace, Clifton, Bristol.
1870. *Inman, William. Upton Manor, Liverpool.

Year of Election.

Ireland, R. S., M.D. 121 Stephen's-green, Dublin.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
1862. ‡ISELIN, J. F., M.A., F.G.S. 52 Stockwell-park-road, London, S.W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. §Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1866. §Jackson, H. W. Springfield, Tooting, Surrey, S.W.
1869. §Jackson, Moses. The Vale, Ramsgate.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
1863. *Jackson-Gwilt, Mrs. H. 24 Hereford-square, Gloucester-road, Brompton, London, S.W.
Jacob, Arthur, M.D. 23 Ely-place, Dublin.
1852. ‡JACOBS, BETHEL. 40 George-street, Hull.
1874. *Jaffe, John. Messrs. Jaffe Brothers, Belfast.
1865. *Jaffray, John. Park-grove, Birmingham.
1872. §James, Christopher. 8 Laurence Pountney Hill, London, E.C.
1859. ‡James, Edward. 9 Gascoyne-terrace, Plymouth.
1860. ‡James, Edward H. 9 Gascoyne-terrace, Plymouth.
JAMES, Colonel Sir HENRY, R.E., F.R.S., F.G.S., M.R.I.A. Ordnance Survey Office, Southampton.
1863. *JAMES, Sir WALTER, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. 9 Gascoyne-terrace, Plymouth.
1863. ‡Jameson, John Henry. 10 Catherine-terrace, Gateshead.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
*JARDINE, Sir WILLIAM, Bart., F.R.S. L. & E., F.L.S. Jardine Hall, Applegarth by Lockerby, Dumfriesshire.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
JARRETT, Rev. THOMAS, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. ‡Jecks, Charles. Billing-road, Northampton.
1870. ‡*Jeffery, F. J. Liverpool.*
1856. ‡Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. 193 St. Vincent-street, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, E.C.; and 25 Devonshire-place, Portland-place, London, W.
1861. *JEFFREYS, J. GWYN, LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S. Ware Priory, Herts.
1852. ‡JELLETT, Rev. JOHN H., M.A., M.R.I.A., Professor of Natural Philosophy in Trinity College, Dublin. 64 Upper Leeson-street, Dublin.
1842. Jellicorse, John. Chaseley, near Rugeley, Staffordshire.
1864. ‡*Jelly, Dr. W.*
1862. §JENKIN, H. C. FLEEMING, F.R.S., Professor of Civil Engineering in the University of Edinburgh. 5 Fettes-row, Edinburgh.
1864. §JENKINS, Captain GRIFFITH, C.B., F.R.G.S. Derwin, Welshpool.
1873. §Jenkins, Major General J. J. 14 St. James's-square, London, S.W.
*Jenkyns, Rev. Henry, D.D. The College, Durham.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.

Year of
Election.

1872. ‡Jennings, W. Grand Hotel, Brighton.
1870. ‡Jerdon, T. C. (Care of Mr. H. S. King, 45 Pall Mall, London, S.W.)
*Jerram, Rev. S. John, M.A. Chobham Vicarage, near Bagshot, Surrey.
1872. §Jesson, Thomas. 3 Clarendon-crescent, Brighton.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *Jevons, W. Stanley, M.A., F.R.S., Professor of Political Economy in Owens College, Manchester. Parsonage-road, Withington, Manchester.
1872. *Joad, George C. Patching, Arundel, Sussex.
1871. *Johnson, David. Irvon Villa, Grosvenor-road, Wrexham.
1865. *Johnson, G. J. 34 Waterloo-street, Birmingham.
1866. §Johnson, John. Knighton Fields, Leicester.
1866. §Johnson, John G. 18a Basinghall-street, London, E.C.
1868. ‡Johnson, J. Godwin. St. Giles's-street, Norwich.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1868. ‡*Johnson, Randall J.*
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. §Johnson, Richard C. Warren Side, Blundell Sands, Liverpool.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1864. ‡Johnson, Thomas. 30 Belgrave-street, Commercial-road, London, E.
Johnson, William. The Wynds Point, Colwall, Malvern, Worcestershire.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
1871. ‡Johnston, A. Keith, F.G.R.S. 1 Savile-row, W.
Johnston, Alexander Robert, F.R.S. Heatherley, near Wokingham.
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
Johnston, Edward. Field House, Chester.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.
*Johnstone, James. Alva House, by Stirling, N.B.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. §Jolly, William (H. M. Inspector of Schools). Inverness, N.B.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1854. ‡*Jones, Rev. Henry H.*
1854. ‡*Jones, John.*
1864. §Jones, John, F.G.S. Saltburn-by-the-Sea, Yorkshire.
1865. ‡Jones, John. 49 Union-passage, Birmingham.
*Jones, Robert. 2 Castle-street, Liverpool.
1854. *Jones, R. L. 6 Sunnyside, Princes Park, Liverpool.
1873. §Jones, Theodore B. 1 Finsbury-circus, E.C.
1847. ‡Jones, Thomas Rymer, F.R.S., Professor of Comparative Anatomy in King's College. 52 Cornwall-road, Westbourne Park, London, W.
1860. ‡Jones, T. Rupert, F.R.S., F.G.S., Professor of Geology and Mineralogy, Royal Military and Staff Colleges, Sandhurst. 5 College-terrace, York Town, Surrey.
1864. §Jones, Sir Willoughby, Bart., F.R.G.S. Cranmer Hall, Fakenham, Norfolk.
*Joule, Benjamin St. John B. Southcliffe, Southport, Lancashire.
1842. *Joule, James Prescott, LL.D., F.R.S., F.C.S. 343 Lower Broughton-road, Manchester.

Year of Election.

1847. ‡JOWETT, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John. Leeds.
1872. ‡Joy, Algernon. 17 Parliament-street, Westminster, S.W.
1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.
Joy, Henry Holmes, LL.D., Q.C., M.R.I.A. Torquay.
Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.
*Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, F.G.S. 6 Manor-view, Brixton.
1863. ‡Jukes, Rev. Andrew. Spring Bank, Hull.

1868. *Kaines, Joseph, M.A., D.Sc., F.A.S.L. 8 Osborne-road, Stroud Green-lane, Hornsey, N.
KANE, Sir ROBERT, M.D., F.R.S., M.R.I.A., Principal of the Royal College of Cork. 51 Stephen's-green, Dublin.
1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, W.
Kay, John Cunliff. Fairfield Hall, near Skipton.
*Kay, John Robinson. Walmersley House, Bury, Lancashire.
Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.
1856. ‡Kay-Shuttleworth, Sir James, Bart. Gawthorpe, Burnley.
1855. ‡Kaye, Robert. Mill Brae, Moodies Burn, by Glasgow.
1872. §Keames, William M. 5 Lower-rock-gardens, Brighton.
1855. ‡*Keddie, William.*
1866. ‡Keene, Alfred. Eastnoor House, Leamington.
1850. ‡KELLAND, Rev. PHILIP, M.A., F.R.S. L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon-crescent, Edinburgh.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1842. Kelsall, J. Rochdale, Lancashire.
1864. *Kemble, Rev. Charles, M.A. Vellore, Bath.
1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.
1857. ‡Kennedy, Lieut-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London, W.C.
Kenny, Matthias. 3 Clifton-terrace, Monkstown, Co. Dublin.
1865. ‡Kenrick, William. Norfolk-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. ‡Kenworth, James Ryley. 7 Pembroke-place, Liverpool.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Auchinraith, near Hamilton, Scotland.
1865. *Kerr, William D., M.D., R.N. Bonnyrigg, Edinburgh.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
1865. *Kinahan, Edward Hudson. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Geological Survey of Ireland. 14 Hume-street, Dublin.
1858. ‡Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne-park, London, W.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.

Year of
Election.

1864. §King, Kelburne, M.D. 27 George-street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. Avonside, Clifton, Bristol.
1842. King, Richard, M.D. 12 Bulstrode-street, London, W.
King, Rev. Samuel, M.A., F.R.A.S. St. Aubins, Jersey.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1862. ‡Kingsley, Rev. Canon Charles, M.A., D.C.L., F.L.S., F.G.S. Eversley Rectory, Winchfield.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1867. *Kinnaird, The Hon. Arthur Fitzgerald, M.P. 1 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1863. ‡Kinnaird, The Right Hon. Lord., K.T., F.G.S. Rossie Priory, Inchture, Perthshire.
Kinnear, J. G., F.R.S.E.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1863. ‡Kirkaldy, David. 28 Bartholomew-road North, London, N.W.
1860. ‡Kirkman, Rev. Thomas P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1870. ‡Kitchener, Frank E. Rugby.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. §Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
Knipe, J. A. Botcherby, Carlisle.
1872. *Knott, George, LL.B., F.R.A.S. Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1842. Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
1870. ‡*Knowles, Rev. J. L.*
*Knox, George James. 37 Liverpool-street, Dover.
1835. Knox, Thomas B. Union Club, Trafalgar-square, London, W.C.
1870. ‡Kynaston, Josiah W. St. Helens, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1862. ‡*Lackerstein, Dr.*
1859. ‡Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1850. ‡Laing, David, F.S.A. Scotl. Signet Library, Edinburgh.
1870. ‡Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co Dublin.
1846. *Laming, Richard. Flansham, near Bognor, Sussex.
1870. ‡Lamport, Charles. Upper Norwood, Surrey.
1871. §Lancaster, Edward. Karesforth Hall, Barnesley.
1859. ‡Lang, Rev. John Marshall. Bank House, Morningside, Edinburgh.
1864. §Lang, Robert. Mancombe, Henbury, Bristol.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Manchester and Salford Bank, Manchester.

Year of Election.

1840. ‡LANKESTER, EDWIN, M.D., LL.D., F.R.S., F.L.S. 68 Belsize-park, N.W.
1865. §LANKESTER, E. RAY, M.A. Exeter College, Oxford.
*LARCOM, Major-General Sir THOMAS AISKEW, K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants.
LASSELL, WILLIAM, F.R.S., F.R.A.S. Ray Lodge, Maidenhead.
1861. *Latham, Arthur G. 24 Cross-street, Manchester.
1870. *Latham, Baldwin. 7 Westminster-chambers, Westminster, S.W.
1845. ‡Latham, Robert G., M.A., M.D., F.R.S. 96 Disraeli-road, Putney, S.W
1870. ‡Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Portsmouth.
1870. *Law, Channell. 5 Champion-park, Camberwell, London, S.E.
1857. ‡Law, Hugh, Q.C. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1869. ‡Lawson, Henry. 8 Nottingham-place, London, W.
1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1868. *LAWSON, M. ALEXANDER, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
LAYCOCK, THOMAS, M.D., Professor of the Practice of Physic in the University of Edinburgh. 4 Rutland-street, Edinburgh.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Capt. R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1847. *LEATHAM, EDWARD ALDAM, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
*Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1858. ‡Leather, John W. Newton Green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1872. ‡LEBOUR, G. A., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1858. ‡Ledgard, William. Potter Newton, near Leeds.
1842. Lee, Daniel. Springfield House, Pendlebury, Manchester.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
Lee, Henry, M.D. Weatheroak, Alve Church, near Bromsgrove.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1859. ‡Lees, William. Link Vale Lodge, Viewforth, Edinburgh.
*Leese, Joseph. Glenfield, Altrincham, Manchester.
*Leeson, Henry B., M.A., M.D., F.R.S., F.C.S The Maples, Bonchurch, Isle of Wight.
1872. ‡LEFEVRE, G. SHAW, M.P., F.R.G.S. 18 Spring-gardens, London, S.W.
*LEFROY, Major-General J. HENRY, R.A., F.R.S., F.R.G.S., Governor of Bermuda. Bermuda.
*Legh, Lieut.-Colonel George Cornwall, M.P. High Legh Hall, Cheshire; and 43 Curzon-street, Mayfair, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. the Earl of. Holkham, Norfolk.

Year of Election.

1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. §Leighton, Andrew. 35 High-park-street, Liverpool.
*LEINSTER, AUGUSTUS FREDERICK, Duke of, M.R.I.A. 6 Carlton House-terrace, London, S.W.; and Carton, Maynooth, Ireland.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1860. ‡Lempriere, Charles, D.C.L. St. John's College, Oxford.
1863. *LENDY, Capt. AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, John, M.D. Tallaght House, Co. Dublin; and 14 Great Dominick-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §Leonard, Hugh, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. ‡Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡LESLIE, T. E. CLIFFE, LL.B., Professor of Jurisprudence and Political Economy, Queen's College, Belfast.
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 10 Farrar's-building, Temple, London, E.C.
1870. ‡Lewis, Alfred Lionel. 151 Church-road, De Beauvoir Town, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1855. ‡*Liddell, John.*
1859. ‡*Ligertwood, George.*
1864. ‡LIGHTBODY, ROBERT, F.G.S. Ludlow, Salop.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, CHARLES GRAVES, D.D., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
*Lindsay, Charles. Ridge Park, Lanark, N.B.
1855. **Lindsay, John H.*
1871. *LINDSAY, The Right Hon. Lord, M.P. 47 Brook-street, London, W.
1871. ‡Lindsay, Rev. T. M. 7 Great Stuart-street, Edinburgh.
1870. ‡Lindsay, Thomas. 288 Renfrew-street, Glasgow.
1842 *Lingard, John R., F.G.S. Mayfield, Shortlands, Bromley, Kent.
Lingwood, Robert M., M.A., F.L.S., F.G.S.
Lister, James. Liverpool Union Bank, Liverpool.
1873. *Lister, Samuel Cunliffe. Farfield Hall, Addingham, Leeds.
1870. §Lister, Thomas. Victoria-crescent, Barnsley.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *LIVEING, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1860. ‡Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.

Year of Election.

1865. ‡Lloyd, G. B. Wellington-road, Edgbaston, Birmingham.
*Lloyd, George, M.D., F.G.S. Park Glass Works, Birmingham.
*LLOYD, Rev. HUMPHREY, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1870. ‡Lloyd, James. 16 Welfield-place, Liverpool.
1870. ‡Lloyd, J. H., M.D. Anglesey, North Wales.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1865. *Lloyd, Wilson. Myrod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington, London, W.
1853. *Locke, John. (Care of J. Robertson, Esq., 3 Grafton-street, Dublin.)
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1872. ‡LOCKE, JOHN, M.P. 63 Eaton-place, London, S.W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. 5 Alexandra-road, Finchley-road, London, N.W.
*LOGAN, Sir WILLIAM EDMOND, LL.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of Canada. Montreal, Canada.
1868. ‡Login, Thomas, C.E., F.R.S.E. India.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. ‡Long, John Jex. 12 Whitevale, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, Frederick. Luamdur, near Derby.
1857. ‡Longfield, Rev. George, D.D. Trinity College, Dublin.
LONGFIELD, MOUNTIFORT, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1861. *Longman, William, F.G.S. 36 Hyde-park-square, London, W.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
Longridge, William S. Oakhurst, Ambergate, Derbyshire.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Summergangs, Hull.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Highfield House Observatory, near Nottingham.
1870. ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1853. *LUBBOCK, Sir JOHN, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms Farnborough, Kent.
1870. ‡Lubbock, Montague. High Elms, Farnborough, Kent.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1867. *Luis, John Henry. Cidhmore, Dundee.
1873. §Lumley, J. Hope Villa, Thornbury, near Bradford.
1866. *Lund, Charles. 1 Blenheim-road, Bradford.
1873. §Lund, Joseph. St. George's-place, Bradford.
1873. §Lund, Joseph. St. George's-place, Bradford.
1850. *Lundie, Cornelius. Tweed Lodge, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.

Year of Election.

1864. *Lupton, Darnton, jun. The Harehills, Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1866. ‡Lycett, Sir Francis. 18 Highbury-grove, London, N.
*Lyell, Sir Charles, Bart., M.A., LL.D., D.C.L., F.R.S., F.L.S., V.P.G.S., Hon. M.R.S.Ed. 73 Harley-street, London, W.
1871. ‡Lyell, Leonard. 42 Regent's Park-road, London, N.W.
1857. ‡Lyons, Robert D. 8 Merrion-square West, Dublin.
1862. *Lyte, F. Maxwell, F.C.S. 6 Cité de Retiro, Faubourg St. Honoré, Paris.
1849. ‡Lyttleton, The Right Hon. Lord, D.C.L., F.R.S. 12 Stratton-street, London, W.

1852. ‡MacAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1868. ‡Macalister, Alexander, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1868. ‡M'Allan, W. A. Norwich.
1866. *M'Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S.W.
1840. Macaulay, James A. M., M.D. 22 Cambridge-road, Kilburn, London, N.W.
1871. ‡M'Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.
*MacBrayne, Robert. Househill Hamlet, Glasgow.
1866. ‡M'Callan, Rev. J. F., M.A. Basford, near Nottingham.
1855. ‡*M'Callum, Archibald K., M.A.*
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, Rev. James, D.D., F.R.S.L., F.G.S. 18 Shaftesbury-terrace, Glasgow.
1840. M'Clelland, James, F.S.S. 32 Pembridge-square, London, W.
1868. ‡M'Clintock, Captain Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *McClure, J. H. Strutt-street, Manchester.
*M'Connel, James. Moore-place, Esher, Surrey.
1859. *M'Connell, David C., F.G.S. 44 Manor-place, Edinburgh.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
Macdonald, William, M.D., F.R.S.E., F.L.S., F.G.S., Professor of Civil and Natural History. St. Andrews, N.B.
1871. §M'Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.)
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
*M'Ewan, John. 13 Hamilton-terrace West, Partick, by Glasgow.
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1871. §M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *M'Farlane, Walter. 231 St. Vincent-street, Glasgow.
1854. *Macfie, Robert Andrew. 13 Victoria-street, Westminster, S.W.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡McGeorge, Mungo. Nithodale, Laurie-park, Sydenham.
1873. §McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford.
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. Wallace-grove, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *M'Intosh, W. C., M.D., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. Water-street, Liverpool.

Year of Election.

1871. §Mackay, Rev. Dr. A., F.R.G.S. 5 Sandford-street, Portobello.
1873. §McKendrick, John G., M.D. 29 Castle-terrace, Edinburgh.
1855. ‡M'Kenzie, Alexander. 89 Buchanan-street, Glasgow.
*Mackenzie, James. Glentore, by Glasgow.
1865. ‡Mackeson, Henry B., F.G.S. Hyde, Kent.
1872. §Mackey, J. A. 24 Buckingham-place, Brighton.
1867. §Mackie, Samuel Joseph, F.G.S. 84 Kensington-park-road, London, W.
*Mackinlay, David. Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. Chichester.
1867. §Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *MacLachlan, Robert, F.L.S. 39 Limes-grove, Lewisham, S.E.
1873. §McLandsborough, John, C.E., F.R.A.S., F.G.S. Shipley, near Bradford.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §MacLaren, Duncan, M.P. Newington House, Edinburgh.
1873. §McLaren, Walter S. B. Newington House, Edinburgh.
1859. ‡Maclear, Sir Thomas, F.R.S., F.R.G.S., F.R.A.S., late Astronomer Royal at the Cape of Good Hope. Cape Town, South Africa.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden-hill-road, London, W.
1868. §M'Leod, Herbert, F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1861. *Maclure, John William. 2 Bond-street, Manchester.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey.
1871. ‡M'Nab, William Ramsay, M.D. Royal Agricultural College, Cirencester.
1870. †Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.
MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MacNeill, Sir John, LL.D., F.R.S., M.R.I.A. 17 The Grove, South Kensington, London, S.W.
1850. ‡Macnight, Alexander. 12 London-street, Edinburgh.
1859. ‡Macpherson, Rev. W. Kilmuir Easter, Scotland.
Macredie, P. B. Mure, F.R.S.E. Irvine, Ayrshire.
1852. *Macrory, Adam John. Duncairn, Belfast.
*Macrory, Edmund, M.A. 40 Leinster-square, Bayswater, London, W.
1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡Macvicar, Rev. John Gibson, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
Magor, J. B. Redruth, Cornwall.
1869. §Main, Rev. R., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1869. ‡Main, Robert. Admiralty, Somerset House, W.C.
1866. §Major, Richard H., F.S.A., F.R.G.S. British Museum, London, W.C.
*Malahide, Talbot de, The Right Hon. Lord, M.A., F.R.S., F.G.S., F.S.A. Malahide Castle, Co. Dublin.
*Malcolm, Frederick. Mordon College, Blackheath, London, S.E.
1870. *Malcolm, Sir James, Bart. The Priory, St. Michael's Hamlet, Aigburth, Liverpool.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
1857. ‡Mallet, Dr. John William, F.C.S., Professor of Chemistry in the University of Virginia, U. S.
*Mallet, Robert, Ph.D., F.R.S., F.G.S., M.R.I.A. The Grove, Clapham-road, Clapham; and 7 Westminster-chambers, Victoria-street, London, S.W.

Year of
Election.

1846. ‡MANBY, CHARLES, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1866. §MANN, ROBERT JAMES, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, The Right Rev. H.
1866. ‡Manning, John. Waverley-street, Nottingham.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1865. ‡March, J. F. Fairfield House, Warrington.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.R.S., F.L.S., F.R.G.S. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S. Stanley Park, Stroud, Gloucestershire.
1871. §MARRECO, A. FRIERE-. College of Physical Science, Newcastle-on-Tyne.
Marriott, John. Allerton, Liverpool.
1857. §Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1866. ‡Marsh, Dr. J. C. L. Park-row, Nottingham.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1856. ‡*Marsh, M. H.*
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
Marshall, James. Headingly, near Leeds.
1852. ‡Marshall, James D. Holywood, Belfast.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1871. ‡Martin, Rev. Hugh, M.A. Greenhill-cottage, Lasswade by Edinburgh.
1870. ‡Martin, Robert, M.D. 120 Upper Brook-street, Manchester.
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. *Martin, William, jun. 3 Airlie-place, Dundee.
*Martindale, Nicholas. Berryarbor, Ilfracombe.
*Martineau, Rev. James. 10 Gordon-street, Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S., Keeper of the Mineralogical Department, British Museum. 112 Gloucester-terrace, Hyde-park-gardens, London, W.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Henry S. King & Co., 65 Cornhill, London, E.C.)
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡Massey, Thomas. 5 Gray's-Inn-square, London, W.C.
1870. ‡Massy, Frederick. 50 Grove-street, Liverpool.
1865. *Mathews, G. S. Portland-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 49 Harborne-road, Birmingham.
1859. ‡Matthew, Alexander C. 3 Canal-terrace, Aberdeen.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
*Matthews, Henry, F.C.S. 60 Gower-street, London, W.C.
1860. §Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.

Year of Election.

1855. ‡Maule, Rev. Thomas, M.A. Partick, near Glasgow.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1864. *Maxwell, Francis. Dunragit, Wigtownshire.
*Maxwell, James Clerk, M.A., LL.D., F.R.S. L. & E. Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B.; and 11 Scroope-terrace, Cambridge.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1865. *May, Walter. Elmley Lodge, Harborne, Birmingham.
1868. §Mayall, J. E., F.C.S. Stork's-nest, Lancing, Sussex.
1863. §Mease, George D. Bylton Villa, South Shields.
1863. ‡Mease, Solomon. Cleveland House, North Shields.
‡Meath, Samuel Butcher, D.D., Lord Bishop of. Ardbraccan, Co. Meath.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1867. ‡Meldrum, Charles. Mauritius.
1866. ‡Mello, Rev. J. M. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1862. §Mennell, Henry J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §Merrifield, Charles W., F.R.S., Principal of the Royal School of Naval Architecture, Superintendent of the Naval Museum at South Kensington, Hon. Sec. I.N.A. 20 Pembroke-gardens, Kensington, London, W.
1872. ‡Merryweather, Richard M. Clapham House, Clapham Common, London, S.W.
1871. ‡Merson, John. Northumberland County Asylum, Morpeth.
1872. *Messent, John. 429 Strand. London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. §Miall, Louis C. Philosophical Hall, Leeds
1847. *Michell, Rev. Richard, D.D., Principal of Magdalen Hall, Oxford.
1865. ‡Michie, Alexander. 26 Austin Friars, London, E.C.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
1859. ‡Millar, John. Lisburn, Ireland.
1863. §Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1865. ‡Miller, Rev. Canon J. C., D.D. The Vicarage, Greenwich, London, S.E.
1861. *Miller, Robert. Broomfield House, Reddish, near Manchester.
Miller, William Hallows, M.A., LL.D., F.R.S., F.G.S., Professor of Mineralogy in the University of Cambridge. 7 Scroope-terrace, Cambridge.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S.. 15 Northumberland-street, Strand, London, W.C.
1842. Milligan, Robert. Acacia in Rawdon, Leeds.
1868. §Mills, Edmund J., D.Sc., F.C.S. 12 Pemberton-terrace, St. John's-park, London, N.
*Mills, John Robert. 11 Bootham, York.
Milne, Admiral Sir Alexander, G.C.B., F.R.S.E. 65 Rutland-gate, London, S.W.
1867. ‡Milne, James. Murie House, Errol, by Dundee.

Year of Election.

1867. *MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1854. *Milner, William. 50 Bentley-road, Liverpool.
1864. *MILTON, The Right Hon. Lord, F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. §Mitchell, Henry. Parkfield House, Bradford.
1870. §Mitchell, John. York House, Clitheroe, Lancashire.
1868. §Mitchell, John, jun. Pole Park House, Dundee.
1862. *MITCHELL, WILLIAM STEPHEN, LL.B., F.L.S., F.G.S. Caius College, Cambridge.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §MOFFAT, THOMAS, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866. §MOGGRIDGE, MATTHEW, F.G.S. Woodfield, Monmouthshire.
1855. §Moir, James. 174 Gallogate, Glasgow.
1861. ‡Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §MOLYNEAUX, WILLIAM, F.G.S. Branston Cottage, Burton-upon-Trent.
1860. ‡Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgeware-road, London, W.
1872. §Moon, W., LL.D. 104 Queen's-road, Brighton.
1857. ‡Moore, Arthur. Cradley House, Clifton, Bristol.
1859. ‡MOORE, CHARLES, F.G.S. 6 Cambridge-terrace, Bath.
1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1871. ‡MORE, ALEXANDER, F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1873. §Morgan, Edward Delmar. 19 Queen's-gardens, London, W.
1868. ‡Morgan, Thomas H. Oakhurst, Hastings.
1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.
1867. ‡Morison, William R. Dundee.
1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, E.C.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1861. ‡*Morris, William.*
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1863. ‡Morrow, R. J. Bentick-villas, Newcastle-on-Tyne.

Year of Election.

1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 21 West Derby-street, Liverpool.
1858. *MORTON, HENRY JOSEPH. Garforth House, West Garforth, near Leeds.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1868. ‡Moseley, H. N. Olveston, Bristol.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1870. §Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1873. *Mosse, George S. 12 Eldon-road, Kensington, W.
1864. *Mosse, J. R. Public Works' Department, Ceylon. (Care of H. S. King & Co., 65 Cornhill, London, E.C.)
1873. §Mossman, William. Woodhall, Calverley, Leeds.
1869. §MOTT, ALBERT J. Claremont House, Seaforth, Liverpool.
1865. §Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. 1 De Montfort-street, Leicester.
1872. §Mott, Miss Minnie. 1 De Montfort-street, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., late Inspector-General of Prisons, Bengal. 12 Durham-villas, Campden-hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. 21 Camden-crescent, Bath.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. Ellenbrook, near Manchester.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1871. ‡Muir, W. Hamilton. Toravon, Stirlingshire.
1872. §Muirhead, Alexander, D.Sc., F.C.S. 159 Camden-road, London, N.
1871. *Muirhead, Henry, M.D. Bushy-hill, Cambuslang, Lanarkshire.
1857. ‡*Mullins, M. Bernard, M.A., C.E.*
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, A. J., M.P., F.R.G.S. The Park, Nottingham.
1864. *MUNRO, Major-General WILLIAM, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1872. *Munster, H. Selwood Lodge, Brighton.
1872. *Munster, William Felix. Selwood Lodge, Brighton.
1864. §MURCH, JEROM. Cranwells, Bath.
*Murchison, John Henry. Surbiton-hill, Kingston, S.W.
1864. *Murchison, K. R. Ashurst Lodge, East Grinstead.
1855. ‡Murdock, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. §Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1850. ‡MURRAY, ANDREW, F.L.S. 67 Bedford-gardens, Kensington, London, W.
1871. ‡Murray, Captain, R.N. Murrathwaite, Ecclefachan, Scotland.
1871. §Murray, Dr. Ivor, F.R.S.E. The Knowle, Brenchley, Staplehurst, Kent.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. §Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. 11 Great Queen-street, Westminster, S.W.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.

Year of Election.

1872. ‡Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1859. *Murton, James. Highfield, Silverdale, Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven. Halifax.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1865. ‡Myers, Rev. E., F.G.S. 3 Waterloo-road, Wolverhampton.
1859. §MYLNE, ROBERT WILLIAM, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1850. ‡Nachot, H. W., Ph.D. 73 Queen-street, Edinburgh.
1842. Nadin, Joseph. Manchester.
1855. *NAPIER, JAMES R., F.R.S. 22 Blythwood-square, Glasgow.
*Napier, Captain Johnstone, C.E. Tavistock House, Salisbury.
1839. *NAPIER, Right Hon. Sir JOSEPH, Bart. 4 Merrion-square South, Dublin.
1855. ‡Napier, Robert. West Chandon, Gareloch, Glasgow.
Napper, James William L. Loughcrew, Oldcastle., Co. Meath.
1872. §Nares, Capt. G. S., R.N. Grant's Bank, Portsmouth.
1866. ‡Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.
1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1864. ‡Natal, William Colenso, Lord Bishop of.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1867. §NEAVES, The Right Hon. Lord. 7 Charlotte-square, Edinburgh.
1873. §Neill, Alexander Renton. Fieldhead House, Bradford.
1873. §Neill, Archibald. Fieldhead House, Bradford.
1853. ‡*Neill, William, Governor of Hull Jail.*
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡Neilson, W. Montgomerie. Glasgow.
Ness, John. Helmsley, near York.
1868. ‡Nevill, Rev. H. R. Great Yarmouth.
1866. *Nevill, Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, C.E., M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡Neville, Parke, C.E. Town Hall, Dublin.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare-hill, Littleborough, Lancashire.
*Newall, Robert Stirling. Ferndene, Gateshead-upon-Tyne.
1866. *Newdigate, Albert L. 18 Esplanade, Dover.
1842. *NEWMAN, Professor FRANCIS WILLIAM. Norwood-villa, Arundel-crescent, Weston-super-Mare.
1863. *NEWMARCH, WILLIAM, F.R.S. Beech Holme, Clapham Common, London, S.W.
1866. *Newmarch, William Thomas. 8 Lovain-crescent, Newcastle-upon-Tyne.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge Magdalen College, Cambridge.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Dean of Guild. Dundee.
1866. §NICHOLSON, Sir CHARLES, Bart., D.C.L., LL.D., M.D., F.G.S., F.R.G.S. 26 Devonshire-place, Portland-place, London, W.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Wellfield, Muswell-hill, London, N.

Year of
Election.

1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
1871. §Nicholson, E. Chambers. Herne-hill, London, S.E.
1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History, University College, Toronto, Canada.
1850. ‡NICOL, JAMES, F.R.S.E., F.G.S., Professor of Natural History in Marischal College, Aberdeen.
1867. ‡Nimmo, Dr. Matthew, L.R.C.S.E. Nethergate, Dundee.
Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
1864. ‡NOAD, HENRY M., Ph.D., F.R.S., F.C.S. 72 Hereford-road, Bayswater, London, W.
1863. *NOBLE, Captain, F.R.S. Elswick Works, Newcastle-on-Tyne.
1870. ‡Nolan, Joseph. 14 Hume-street, Dublin.
1860. *Nolloth, Captain Matthew S., R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §NORMAN, Rev. ALFRED MERLE, M.A. Burnmoor Rectory, Fence, House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
Norris, Charles. St. John's House, Halifax.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. §Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1866. ‡North, Thomas. Cinder-hill, Nottingham.
NORTHAMPTON, The Right Hon. CHARLES DOUGLAS, Marquis of. 145 Piccadilly, London, W.: and Castle Ashby, Northamptonshire.
1869. ‡NORTHCOTE, The Right Hon. Sir STAFFORD H., Bart., C.B., M.P. Pynes, Exeter; and 86 Harley-street, London, W.
*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.

O'Beirne, James, M.D.
O'Brien, Baron Lucius. Dromoland, Newmarket-on-Fergus, Ireland.
O'Callaghan, George. Tallas, Co. Clare.
1858. *O'CALLAGHAN, PATRICK, LL.D., D.C.L. Comyn Villa, Lansdown-road, Tunbridge Wells.
Odgers, Rev. William James. Savile House, Weston-road, Bath.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. Museum, Oxford.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. ‡O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1866. ‡Ogden, James. Woodhouse, Loughborough.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*OGILVIE, GEORGE, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. 29 Union-place, Aberdeen.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
1863. ‡OGILVY, Sir JOHN, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. 98 Friar-gate, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John. 22 Upper Fitzwilliam-street, Dublin.
1862. ‡O'Kelly, Joseph, M.A. 51 Stephen's-green, Dublin.
1857. ‡O'Kelly, Matthias J. Dalkey, Ireland.
1853. §OLDHAM, JAMES, C.E. Cottingham, near Hull.

Year of Election.

1857. *Oldham, Thomas, M.A., LL.D., F.R.S., F.G.S., M.R.I.A., Director of the Geological Survey of India. 1 Hastings-street, Calcutta.
1860. ‡O'Leary, Professor Purcell, M.A. Sydney-place, Cork.
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew.
*Ommanney, Vice-Admiral Erasmus, C.B., F.R.S., F.R.A.S., F.R.G.S. 6 Talbot-square, Hyde Park, London, W.; and United Service Club, Pall Mall, London, S.W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1842. Ormerod, George Wareing, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham-hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
Orpen, John H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1854. ‡Orr, Sir Andrew. Blythwood-square, Glasgow.
1873. §Osborn, George. 11 Blenheim-mount, Bradford.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. South Bank, Edgbaston, Birmingham.
1854. ‡Outram, Thomas. Greetland, near Halifax.
Overstone, Samuel Jones Lloyd, Lord, F.G.S. 2 Carlton-gardens, London, S.W.; and Wickham Park, Bromley.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
Owen, Richard, M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1863. *Ower, Charles, C.E. 11 Craigie-terrace, Dundee.

1859. ‡Page, David, LL.D., F.R.S.E., F.G.S. College of Physical Science, Newcastle-upon-Tyne.
1863. ‡Paget, Charles. Ruddington Grange, near Nottingham.
1872. *Paget, Joseph. Ruddington Grange, near Nottingham.
1870. *Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1873. §Palmer, George. The Acacias, Reading, Berks.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R. Phœnix Lodge, Brixton, London, S.W.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea, Hull.
1857. *Parker, Alexander, M.R.I.A.. 59 William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
Parker, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard. Dunscombe, Cork.
1865. *Parker, Walter Mantel. High-street, Alton, Hants.
Parker, Rev. William. Saham, Norfolk.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. King's Norton, near Birmingham.
1864. §Parkes, William. 23 Abingdon-street, Westminster, S.W.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.

Year of Election.

1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1865. *Parsons, Charles Thomas. 8 Portland-road, Edgbaston, Birmingham.
1855. ‡Paterson, William. 100 Brunswick-street, Glasgow.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. H. Craigdarragh, Belfast.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1871. ‡*Patterson, John.*
1863. ‡Pattinson, John. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-on-Tyne.
1867. §Pattison, Samuel R., F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1863. §PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1851. ‡Payne, Joseph. 4 Kildare-gardens, Bayswater, London, W.
1866. ‡Payne, Dr. Joseph F. 4 Kildare-gardens, Bayswater, London, W.
1847. ‡PEACH, CHARLES W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1868. ‡Peacock, Ebenezer. 32 University-street, London, W.C.
1863. §Peacock, Richard Atkinson. 12 Queen's-road, Jersey.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, E.C.
Pearson, Charles. 10 Torrington-square, London, W.C.
1872. *Pearson, Joseph. 54 Welbeck-terrace, Mansfield-road, Nottingham.
1870. ‡Pearson, Rev. Samuel. 3 Greenheys-road, Prince's Park, Liverpool.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. *Pease, Joseph W., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.L.S., F.R.G.S. Harecroft House, Wisbeach, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibaldsholme, Wisbeach, Cambridgeshire.
*Peckover, William, F.S.A. Wisbeach, Cambridgeshire.
*Peel, George. Soho Iron Works, Manchester.
1873. §Peel, Thomas. Hampton-place, Horton, Yorkshire.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.
1868. ‡Pendergast, Thomas. Lancefield, Cheltenham.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Government School of Mines. Museum of Practical Geology, Jermyn-street, S.W.; and 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Chatcots, Belsize Park, London, N.W.
1868. *PERKIN, WILLIAM HENRY, F.R.S., F.C.S. Seymour Villa, Sudbury, Harrow.
1861. ‡Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.

Year of Election.

1864. *Perkins, V. R. The Brands, Wotton-under-Edge, Gloucestershire.
1867. ‡*Perkins, William.*
1861. ‡Perring, John Shae. 104 King-street, Manchester.
Perry, The Right Rev. Charles, M.A., Bishop of Melbourne, Australia.
*Perry, Rev. S. G. F., M.A. Tottington Parsonage, near Bury.
1870. *Perry, Rev. S. J. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 108 Marina, St. Leonards-on-Sea.
1867. ‡Phayre, Colonel Sir Arthur. East India United Service Club, St. James's-square, London, S.W.
1863. *Phené, John Samuel, F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. §Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
*Philips, Mark. Welcombe, Stratford-on-Avon.
Philips, Robert N. The Park, Manchester.
1863. ‡Philipson, Dr. 1 Saville-row, Newcastle-on-Tyne.
1859. *Phillips, Major-General Sir B. Travell. United Service Club, Pall Mall, London, W.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1870. ‡Phillips, J. Arthur. Cressington Park, Aigburth, Liverpool.
*Phillips, John, M.A., LL.D., D.C.L., F.R.S., F.G.S., Professor of Geology in the University of Oxford. Museum House, Oxford.
1859. ‡*Phillips, Major J. Scott.*
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡Phipson, T. L., Ph.D. 4 The Cedars, Putney, Surrey.
1864. ‡Pickering, William. Oak View, Clevedon.
1861. ‡Pickstone, William. Radcliff Bridge, near Manchester.
1870. §Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. §Pigot, Rev. E. V. Malpas, Cheshire.
1871. ‡Pigot, Thomas F. Royal College of Science, Dublin.
*Pike, Ebenezer. Besborough, Cork.
1865. ‡Pike, L. Owen. 25 Carlton-villas, Maida-vale, London, W.
1873. §Pike, W. H. 4 The Grove, Highgate, N.
1857. ‡Pilkington, Henry M., M.A., Q.C. 35 Gardiner's-place, Dublin.
1863. *Pim, Captain Bedford C. T., R.N., M.P., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brennan's Town, Cabinteely, Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
Pim, William H. Monkstown, Dublin.
1861. ‡*Pincoffs, Simon.*
1868. ‡Pinder, T. R. St. Andrews, Norwich.
1859. ‡Pirrie, William, M.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1869. §Plant, James, F.G.S. 40 West-terrace, West-street, Leicester.
1865. ‡Plant, Thomas L. Camp-hill, and 33 Union-street, Birmingham.
1867. ‡Playfair, Lieut.-Colonel, H.M. Consul, Algeria.
1842. Playfair, Lyon, C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 4 Queensberry-place, South Kensington, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *Pochin, Henry Davis, F.C.S. Broughton Old Hall, Manchester.

Year of Election.

1846. ‡POLE, WILLIAM, Mus. Doc., F.R.S. The Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. East Witton Vicarage, Bedale, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Pooley, Thomas A., B.Sc. South Side, Clapham Common, London, S.W.
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
*PORTER, HENRY J. KER, M.R.I.A. New Traveller's Club, 15 George-street, Hanover-square, London, W.
1866. §Porter, Robert. Beeston, Nottingham.
Porter, Rev. T. H., D.D. Desertcreat, Co. Armagh.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*POTTER, EDMUND, F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
1863. ‡Potts, James. 26 Sandhill, Newcastle-on-Tyne.
1857. *POUNDEN, Captain LONSDALE, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1864. ‡*Prangley, Arthur.*
1869. *Preece, William Henry. Grosvenor House, Southampton.
1864. *Prentice, Manning. Violet-hill, Stowmarket, Suffolk.
Prest, The Venerable Archdeacon Edward. The College, Durham.
Prest, John. Blossom-street, York.
*PRESTWICH, JOSEPH, F.R.S., F.G.S. Shoreham, near Sevenoaks.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-Fields, London, W.C.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. 11 St. Giles's-street, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
Price, J. T. Neath Abbey, Glamorganshire.
1870. §Price, Captain W. E., M.P. Tibberton Court, Gloucester.
1865. *Prichard, Thomas, M.D. Abington Abbey, Northampton.
1865. ‡Prideaux, J. Symes. 209 Piccadilly, London, W.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.R.A.S., F.G.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1871. ‡Procter, James. Morton House, Clifton, Bristol.
1863. ‡Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.

Year of Election.

1872. *Pryor, M. Robert. High Elms, Watford.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1864. ‡Pugh, John. Aberdovey, Shrewsbury.
1873. §Pullan, Lawrence. Bridge of Allan, N.B.
1867. ‡Pullar, John. 4 Leonard Bank, Perth.
1867. §Pullar, Robert. 6 Leonard Bank, Perth.
1842. *Pumphrey, Charles. 33 Frederick-road, Edgbaston, Birmingham.
Punnett, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1869. ‡*Purchas, Rev. W. H.*
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1866. ‡Purser, Professor John. Queen's College, Belfast.
1860. *Pusey, S. E. B. Bouverie-. 36 Lowndes-street, S.W.; and Pusey House, Faringdon.
1868. §PYE-SMITH, P. H., M.D. 31 Finsbury-square, E.C.; and Guy's Hospital, London, S.E.
1861. *Pyne, Joseph John. St. German's Villa, St. Lawrence-road, Notting-hill, W.

1870. ‡Rabbits, W. T. Forest-hill, London, S.E.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
*Radford, William, M.D. Sidmount, Sidmouth.
1861. ‡Rafferty, Thomas. 13 Monmouth-terrace, Rusholme, Manchester.
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. ‡Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.
1855. ‡Rainey, Harry, M.D. 10 Moore-place, Glasgow.
1864. ‡Rainey, James T. 8 Widcomb-crescent, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, jun., F.G.S. 45 Norland-square, Notting-hill, London, W.
1845. ‡RAMSAY, ANDREW CROMBIE, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Economic Geology, Professor of Geology in the Royal School of Mines. Geological Survey Office, Jermyn-street, London, S.W.
1863. ‡*Ramsay, D. R.*
1867. ‡Ramsay, James, jun. Dundee.
1861. ‡Ramsay, John. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 15 Somerset-street, Portman-square, London, W.
1873. *Ramsden, William. Bracken Hall, Horton, Yorkshire.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker, LL.M. 62 St. Andrew's-street, Cambridge.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1855. ‡Randolph, Charles. Pollockshiels, Glasgow.
1860. *Randolph, Rev. Herbert, M.A. Marcham, near Abingdon.
Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1863. §Ransom, William Henry, M.D., F.R.S. Low Pavement, Nottingham
1861. §Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1868. *Ranson, Edwin. Kempston Mill, Bedford.

Year of Election.

1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's-Inn, London, W.C.

Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.

1868. ‡*Rassam, Hormuzed.*

*RATCLIFF, Colonel CHARLES, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.

1864. §Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.

1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.

1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.

1870. §Rathbone, R. R. 11 Rumford-street, Liverpool.

1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.

Rawdon, William Frederick M.D. Bootham, York.

1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.

*Rawlins, John. Shrawley Wood House, near Stourport.

1866. *RAWLINSON, GEORGE, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.

1855. *RAWLINSON, Major-General Sir HENRY C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.

1868. *RAYLEIGH, The Right Hon. Lord, M.A., F.R.S. 4 Carlton-gardens, Pall Mall, S.W.; and Terling Place, Witham, Essex.

1865. ‡Rayner, Henry. West View, Liverpool-road, Chester.

1870. ‡Rayner, Joseph (Town Clerk). Liverpool.

1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.

1865. ‡Read, William. Albion House, Epworth, Bawtry.

*Read, W. H. Rudstone, M.A., F.L.S. 12 Blake-street, York.

1870. §Reade, Thomas M., C.E., F.C.S. Blundell Sands, Liverpool.

1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. Knockranny, Keadue, Carrick-on-Shannon, Ireland.

1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.

1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.

1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.

Redwood, Isaac. Cae Wern, near Neath, South Wales.

1861. *Reé, H. P. Villa Ditton, Torquay.

1861. ‡REED, EDWARD J., Vice-President of the Institute of Naval Architects. Chorlton-street, Manchester.

1869. ‡Reid, J. Wyatt. 40 Great Western-terrace, Bayswater, London, W.

1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.

1863. §Renals, E. 'Nottingham Express' Office, Nottingham.

1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.

RENNIE, Sir JOHN, Knt., F.R.S., F.G.S., F.S.A., F.R.G.S. Lowndes-square, London, S.W.

1860. ‡Rennison, Rev. Thomas, M.A. Queen's College, Oxford.

1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.

1869. ‡Révy, J. J. 16 Great George-street, Westminster, S.W.

1870. *REYNOLDS, OSBORNE, M.A., Professor of Engineering in Owens College, Manchester.

1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.

1871. ‡Reynolds, S. R. Royal Dublin Society, Kildare-street, Dublin.

Reynolds, William, M.D.

1858. *Rhodes, John. 18 Albion-street, Leeds.

1868. §RICHARDS, Rear-Admiral GEORGE H., C.B., F.R.S., F.R.G.S., Hydrographer to the Admiralty. The Admiralty, Whitehall, London, S.W.

1863. §RICHARDSON, BENJAMIN WARD, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.

1861. §Richardson, Charles. 10 Berkeley-square, Bristol.

Year of Election.

1869. *Richardson, Charles. Albert Park, Abingdon, Berks.
1863. *Richardson, Edward, jun. 3 Lovaine-place, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡Richardson, J. H. 3 Arundel-terrace, Cork.
1868. §Richardson, James C. Glanrafon, near Swansea.
1863. ‡Richardson, John W. South Ashfield, Newcastle-on-Tyne.
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
Richardson, William. Micklegate, York.
1861. §Richardson, William. 4 Edward-street, Werneth, Oldham.
1861. ‡Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.
1863. ‡Richter, Otto, Ph.D. 7 India-street, Edinburgh.
1870. ‡Rickards, Dr. 36 Upper Parliament-street, Liverpool.
1868. §Ricketts, Charles, M.D., F.G.S. 22 Argyle-street, Birkenhead.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1859. ‡Riddell, Rev. John. Moffat by Beatlock, N.B.
1861. *Rideout, William J. 51 Charles-street, Berkeley-square, London, W.
1872. §Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Akroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
1873. §Ripley, Edward. Acacia, Apperley, near Leeds.
1873. §Ripley, H. W. Acacia, Apperley, near Leeds.
*RIPON, The Marquis of, K.G., D.C.L., F.R.S., F.L.S. 1 Carlton-gardens, London, S.W.
1860. ‡Ritchie, George Robert. 4 Watkyn-terrace, Coldharbour-lane, Camberwell, London, S.E.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. 65 Porchester-terrace, Hyde Park, London, W.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *ROBBINS, J. 104 Portsdown-road, Maida-hill, London, N.W.
Roberton, John. Oxford-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F.S.A. Athenæum Club, London, S.W.
1870. *Roberts, Isaac, F.G.S. 26 Rock-park, Rock-ferry, Cheshire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
1868. §ROBERTS, W. CHANDLER, F.G.S., F.C.S. Royal Mint, London, E.
*Roberts, William P. 38 Red-lion-square, London, W.C.
1866. ‡Robertson, Alister Stuart, M.D., F.R.G.S. Horwich, Bolton, Lancashire.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1867. §Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. Bank, High-street, Manchester.
1866. ‡ROBERTSON, WILLIAM TINDAL, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
*Robinson, H. Oliver. 6 South-street, Finsbury, London, E.C.
1873. §Robinson, Hugh. Donegal-street, Belfast.
1866. ‡Robinson, John. Museum, Oxford.
1861. ‡Robinson, John. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.

Year of Election.

1855. ‡Robinson, M. E. 116 St. Vincent-street, Glasgow.
1860. ‡Robinson, Admiral Robert Spencer. 61 Eaton-place, London, S.W.
ROBINSON, Rev. THOMAS ROMNEY, D.D., F.R.S., F.R.A.S., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 20 Great George-street, Westminster, S.W.
*Robson, Rev. John, M.A., D.D Ajmére Lodge, Cathkin-road, Langside, Glasgow.
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. 3 Palmerston-road, Grange, Edinburgh.
1872. §RODWELL, GEORGE F., F.R.A.S., F.C.S., Lecturer on Natural Philosophy at Guy's Hospital. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1861. §ROFE, JOHN, F.G.S. 7 Queen-street, Lancaster.
1860. ‡ROGERS, JAMES E. THOROLD, Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1869. *Rogers, Nathaniel, M.D. 34 Paul-street, Exeter.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1859. ‡ROLLESTON, GEORGE, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.
1863. ‡Romilly, Edward. 14 Hyde Park-terrace, London, W.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clark Samuel, F.G.S., F.L.S. Palgrave House, Eastbourne.
1865. ‡Roper, R. S., F.G.S. Cwmbrae Iron Works, Newport, Monmouthshire.
1855. *ROSCOE, HENRY ENFIELD, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1861. ‡ROSE, C. B., F.G.S. 25 King-street, Great Yarmouth, Norfolk.
1863. ‡Roseby, John. Haverholme House, Brigg, Lincolnshire.
1857. ‡Ross, David, LL.D. Drumbrain Cottage, Newbliss, Ireland.
1872. §Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1861. *Ross, Thomas. 7 Wigmore-street, Cavendish-square, London, W.
1842. Ross, William. Pendleton, Manchester.
1869. *ROSSE, The Right Hon. The Earl of, D.C.L., F.R.S., F.R.A.S. Birr Castle, Parsonstown, Ireland; and 32 Lowndes-square, London, S.W.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1849. §Round, Daniel G. Hange Colliery, near Tipton, Staffordshire.
1861. ‡Routh, Edward J., M.A. St. Peter's College, Cambridge.
1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India (care of King & Co., 45 Pall Mall, London).
1861. ‡Rowan, David. Elliot-street, Glasgow.
1855. ‡*Rowand Alexander.*
1865. §Rowe, Rev. John. Load Vicarage, Landport, Somerset.
1855. *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Palmyra-crescent, Galway.
*Rowntree, Joseph. Leeds.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.

Year of Election.

1869. §Rudler, F. W., F.G.S. 6 Pond-street, Hampstead, London, N.W.
1856. ‡Rumsay, Henry Wildbore. Gloucester Lodge, Cheltenham.
1873. §Rushforth, Joseph. 43 Ash-grove, Horton-lane, Bradford.
1847. ‡RUSKIN, JOHN, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Corpus Christi College, Oxford.
1857. ‡Russell, Rev. C. W., D.D. Maynooth College.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
1859. ‡RUSSELL, The Right Hon. JOHN, Earl, K.G., F.R.S., F.R.G.S. 37 Chesham-place, Belgrave-square, London, S.W.
Russell, John. 15 Middle Gardiner's-street, Dublin.
RUSSELL, JOHN SCOTT, M.A., F.R.S. L. & E. Sydenham; and 5 Westminster Chambers, London, S.W.
1852. *Russell, Norman Scott. 5 Westminster-chambers, London, S.W.
1863. ‡Russell, Robert. Gosforth Colliery, Newcastle-on-Tyne.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1862. §RUSSELL, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.
1865. ‡Rust, Rev. James, M.A. Manse of Slains, Ellon, N.B.
1871. §RUTHERFORD, WILLIAM, M.D., Professor of Physiology in King's College. 12 Upper Berkeley-street, W.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1871. ‡*Ruttledge, T. E.*
*Ryland, Arthur. The Linthurst Hill, Broomsgrove, Worcestershire.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1853. ‡*Rylands, Joseph.*
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

*SABINE, General Sir EDWARD, K.C.B., R.A., LL.D., D.C.L., F.R.S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865. ‡Sabine, Robert. Auckland House, Willesden-lane, London, N.W.
1871. §Sadler, Samuel Camperdowne. Purton Court, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1848. ‡St. DAVIDS, The Right Rev. CONNOP THIRLWALL, D.D., F.G.S., Lord Bishop of. Abergwili, Carmarthen.
Salkeld, Joseph. Penrith, Cumberland.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1873. *SALOMONS, Sir DAVID, Bart. Broom-hill, Tunbridge Wells.
1858. *SALT, Sir TITUS, Bart. Crow-Nest, Lightcliffe, near Halifax.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. 32 The Grove, Boltons, London, S.W.
1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1867. ‡Samuelson, Edward. Roby, near Liverpool.
1870. ‡SAMUELSON, JAMES. St. Domingo-grove, Everton, Liverpool.
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1857. ‡Sanders, Gilbert. The Hill, Monkstown, Co. Dublin.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.
*SANDERS, WILLIAM, F.R.S., F.G.S. Hanbury Lodge, The Avenue, Clifton, Bristol.
1871. ‡Sanders, William R., M.D. 11 Walker-street, Edinburgh.
1872. §SANDERSON, J. S. BURDON, M.D., F.R.S. 49 Queen Anne-street, London, W.

Year of Election.

1872. Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, The Right Hon. Lord, M.P. 39 Gloucester-square, London, W.
1873. §Sands, T. C. 24 Spring-gardens, Bradford.
1865. ‡Sargant, W. L. Edmund-street, Birmingham.
Satterfield, Joshua. Alderley Edge.
1861. ‡Saul, Charles J. Smedley-lane, Cheetham-hill, Manchester.
1868. ‡Saunders, A., C.E. King's Lynn.
1846. ‡Saunders, Trelawney W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1863. ‡Savory, Valentine. Cleckheaton, near Leeds.
1872. §Sawyer, George David. 55 Buckingham-place, Brighton.
1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1857. ‡Scallan, James Joseph. 77 Harcourt-street, Dublin.
1850. ‡Scarth, Pillans. 2 James's-place, Leith.
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
1872. ‡SCHENCK, ROBERT, Ph.D. 398 Manor-terrace, Brixton, S.W.
*Schlick, Count Benj. Quai Voltaire, Paris.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
*Scholes, T. Seddon. 10 Warwick-place, Leamington.
1847. *Scholey, William Stephenson, M.A. Freemantle Lodge, Bath-road, Reading.
SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1873. *Schuster, Arthur, Ph.D. Sunnyside, Upper Avenue-road, Regent's Park, N.W.
1861. *Schwabe, Edmund Salis. Rhodes House, near Manchester.
1847. ‡SCLATER, PHILIP LUTLEY, M.A, Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. 11 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1865. §SCOTT, Major-General E. W. S., Royal Bengal Artillery. Treledan Hall, Welshpool, Montgomeryshire.
1859. ‡*Scott, Captain Fitzmaurice. Forfar Artillery.*
1872. ‡Scott, George, Curator of the Free Library and Museum, Brighton. 6 Western-cottages, Brighton.
1872. §Scott, Major-General H. Y. D., C.B. Sunnyside, Ealing.
1871. ‡Scott, James S. T. Monkrigg, Haddingtonshire.
1857. §SCOTT, ROBERT H., M.A., F.R.S., F.G.S., Director of the Meteorological Office. 116 Victoria-street, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1864. ‡Scott, Wentworth Lascelles. Wolverhampton.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. §Scott, William Bower. Chudleigh, Devon.
1864. ‡Scott, William Robson, Ph.D. St. Leonards, Exeter.
1869. ‡Searle, Francis Furlong. 5 Cathedral-yard, Exeter.
1859. ‡Seaton, John Love. Hull.
1870. ‡Seaton, Joseph, M.D. Halliford House, Sandbury.
1861. *SEELEY, HARRY GOVIER, F.L.S., F.G.S. 31 Soho-square, London, W.; and St. John's College, Cambridge.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
*SELWYN, Rev. Canon WILLIAM, M.A., D.D., F.R.S., Margaret Professor of Divinity in the University of Cambridge. Vine Cottage, Cambridge.

Year of Election.

1873. §Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1858. *Senior, George, F.S.S. Rose-hill, Dodworth, near Barnsley.
1870. *Sephton, Rev. J. 166 Bedford-street, Liverpool.
1873. §Sewell, E., M.A., F.R.G.S. Ilkley College, near Leeds.
1868. ‡Sewell, Philip E. Catton, Norwich.
Seymour, George Hicks. Stonegate, York.
1861. *Seymour, Henry D. 209 Piccadilly, London, W.
Seymour, John. 21 Bootham, York.
1853. ‡Shackles, G. L. 6 Albion-street, Hull.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871. *Shand, James. Eliot Bank, Sydenham-hill, London, S.E.
1867. §Shanks, James. Den Iron Works, Arbroath, N. B.
1869. *Shapter, Dr. Lewis. The Barnfield, Exeter.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. §SHARP, SAMUEL, F.G.S., F.S.A. Dallington Hall, near Northampton.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
SHARPEY, WILLIAM, M.D., LL.D., F.R.S., F.R.S.E., Professor of Anatomy and Physiology in University College. Lawnbank, Hampstead, London, N.W.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
1839. Shepard, John. 41 Drewton-street, Manningham-road, Bradford.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1869. ‡Sherard, Rev. S. H. Newton Abbot, Devon.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. §Shinn, William C. (ASSISTANT GENERAL TREASURER). Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1870. *Shoolbred, James N., C.E., F.G.S. 3 York-buildings, Dale-street, Liverpool.
1842. Shuttleworth, John. Wilton Polygon, Cheetham-hill, Manchester.
1866. ‡SIBSON, FRANCIS, M.D., F.R.S. 59 Brook-street, London, W.
1861. *Sidebotham, Joseph. 19 George-street, Manchester.
1872. *Sidebottom, Robert. Mersey Bank, Heaton Mersey, Manchester.
1873. §Sidgwick, R. H. The Raikes, Skipton.
1857. ‡Sidney, Frederick John, LL.D., M.R.I.A. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 8 Park-street, Westminster, S.W.
1856. *SIEMENS, C. WILLIAM, D.C.L., F.R.S. 8 Park-street, Westminster, S.W.
*Sillar, Zechariah, M.D. Bath House, Laurie Park, Sydenham, London, S.E.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1865. §Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.

Year of Election.

1852. ‡Simms, William. Albion-place, Belfast.
1847. ‡Simon, John, D.C.L., F.R.S. 40 Kensington-square, London, W.
1866. †Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Marykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
*Simpson, Rev. Samuel. Greaves House, near Lancaster.
Simpson, Thomas. Blake-street, York.
Simpson, William. Bradmore House, Hammersmith, London, W.
1859. ‡Sinclair, Alexander. 133 George-street, Edinburgh.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.
1870. *Sinclair, W. P. 32 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, Baboo Mohendro Lall, M.D. 1344 San Kany, Tollah-street, Calcutta, per Messrs. Harrenden & Co., 3 Chapel-place, Poultry, London, E.C.
1865. §Sissons, William. 92 Park-street, Hull.
1870. §Sladen, Walter Percy, F.G.S. Exley House, near Halifax.
1873. §Slater, Clayton. Barnoldswick, near Leeds.
1870. §Slater, W. B. 28 Hamilton-square, Birkenhead.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1853. ‡Sleddon, Francis. 2 Kingston-terrace, Hull.
1849. §Sloper, George Edgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §Sloper, S. Elgar. Winterton, near Southampton.
1872. ‡Smale, John, Chief Justice of Hong Kong.
1867. ‡Small, David. Gray House, Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1867. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1868. §Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey.
1857. ‡Smith, Aquila, M.D., M.R.I.A. 121 Lower Bagot-street, Dublin.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead-heath, London, N.W.
1873. §Smith, C. Sidney College, Cambridge.
1865. §SMITH, DAVID, F.R.A.S. 4 Cherry-street, Birmingham.
1859. §SMITH, EDWARD, M.D., LL.B., F.R.S. 140 Harley-street, London, W.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
*SMITH, Rev. GEORGE SIDNEY, D.D., M.R.I.A., Professor of Biblical Greek in the University of Dublin. Riverland Glebe, Omagh, Ireland.
*SMITH, HENRY JOHN STEPHEN, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford. 64 St. Giles's, Oxford.
1860. *Smith, Heywood, M.A., M.D. 2 Portugal-street, Grosvenor-square, London, W.
1865. ‡*Smith, Isaac.*
1870. ‡Smith, James. 146 Bedford-street South, Liverpool.
1873. §Smith, James. Liverpool.
1853. ‡Smith, John. York City and County Bank, Malton, Yorkshire.

Year of Election.

1871. *Smith, John Alexander, M.D., F.R.S.E. 7 West Maitland-street, Edinburgh.
1867. *Smith, John P., C.E. 67 Renfield-street, Glasgow.
Smith, John Peter George. Spring Bank, Anfield, Liverpool.
1852. *Smith, Rev. Joseph Denham. Bellevue, Blackrock, Co. Dublin.
*Smith, Philip, B.A. 26 South-hill-park, Hampstead, London, N.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §SMITH, ROBERT ANGUS, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. §Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. §Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas (Sheriff). Dundee.
1867. ‡Smith, Thomas. Pole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1857. §SMITH, WILLIAM, C.E., F.G.S., F.R.G.S. 18 Salisbury-street, Adelphi, London, W.C.
1871. ‡Smith, William Robertson. Aberdeen.
1850. *SMYTH, CHARLES PIAZZI, F.R.S. L. & E., F.R.A.S., Astronomer Royal for Scotland, Professor of Practical Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1870. §Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.
1870. ‡Smyth, H. L. Crabwall Hall, Cheshire.
1857. *SMYTH, JOHN, jun., M.A., M.I.C.E.I., F.M.S. Milltown, Banbridge, Ireland.
1868. ‡Smyth, Rev. J. D. Hurst. 13 Upper St. Giles's-street, Norwich.
1864. ‡SMYTH, WARINGTON W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 92 Inverness-terrace, Bayswater, London, W.
1854. ‡Smythe, Colonel W. J., R.A., F.R.S. Bombay.
Soden, John. Athenæum Club, Pall Mall, London, S.W.
1853. ‡Sollitt, J. D., Head Master of the Grammar School, Hull.
*SOLLY, EDWARD, F.R.S., F.L.S., F.G.S., F.S.A. Sandcotes, near Poole.
*SOPWITH, THOMAS, M.A., F.R.S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, S.W.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, F.R.S., F.G.S. Broomfield, Sheffield.
1865. *Southall, John Tertius. Leominster.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Greenbank, Darlington.
1859. ‡Spence, Rev. James, D.D. 6 Clapton-square, London, N.E.
*Spence, Joseph. 60 Holgate Hill, York.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Bute House, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.

Year of
Election.

1855. ‡Spens, William. 78 St. Vincent-street, Glasgow.
1871. ‡Spicer, George. Broomfield, Halifax.
1864. *Spicer, Henry, jun., F.L.S., F.G.S. 22 Highbury-crescent; and 19 New Bridge-street, Blackfriars, London, E.C.
1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1847. *Spiers, Richard James, F.S.A. Huntercombe, Oxford.
1868. *Spiller, Edmund Pim. 3 Furnival's Inn, London, E.C.
1864. *SPILLER, JOHN, F.C.S. 35 Grosvenor-road, Highbury-new-park, London, N.
1846. *SPOTTISWOODE, WILLIAM, M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. (GENERAL TREASURER). 50 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 50 Grosvenor-place, London, S.W.
1854. *Sprague, Thomas Bond. 6 Buckingham-terrace, Edinburgh.
1853. ‡Spratt, Joseph James. West-parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.
1858. *STAINTON, HENRY T., F.R.S., Sec.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1851. *Stainton, James Joseph, F.L.S. Horsell, near Ripley, Surrey.
1865. §STANFORD, EDWARD C. C. Edinbarnet, Dumbartonshire, N.B.
1837. Staniforth, Rev. Thos. Storrs, Windermere.
STANLEY, The Very Rev. ARTHUR PENRHYN, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.
Stapleton, H. M. 1 Mountjoy-place, Dublin.
1866. ‡Starey, Thomas R. Daybrook House, Nottingham.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. The Knoll, Baildon, near Leeds.
1857. ‡Steale, William Edward, M.D. 15 Hatch-street, Dublin.
1870. ‡Stearn, C. H. 3 Elden-terrace, Rock Ferry, Liverpool.
1863. §Steele, Rev. Dr. 2 Bathwick-terrace, Bath.
1873. §Steinthal, G. A. 15 Hallfield-road, Bradford.
1861. ‡Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
STENHOUSE, JOHN, LL.D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1872. ‡Stennett, Mrs. Eliza. 2 Clarendon-terrace, Brighton.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1863. §Sterriker, John. Driffield.
1872. §Sterry, William. Union Club, Pall Mall, London, S.W.
1870. *Stevens, Miss Anna Maria. Wylye, near Heytesbury, Bath.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1863. *Stevenson, Archibald. 2 Wellington-crescent, South Shields.
1850. ‡Stevenson, David. 8 Forth-street, Edinburgh.
1868. ‡Stevenson, Henry, F.L.S. Newmarket-road, Norwich.
1863. *STEVENSON, JAMES C., M.P. Westoe, South Shields.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester.
1864. ‡STEWART, CHARLES, F.L.S. 19 Princess-square, Plymouth.
1856. *Stewart, Henry Hutchinson, M.D., M.R.I.A. 75 Eccles-street, Dublin.
1847. ‡Stewart, Robert, M.D. The Asylum, Belfast.
1867. ‡Stirling, Dr. D. Perth.
1868. ‡Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1867. *Stirrup, Mark. 14 Atkinson-street, Deangate, Manchester.
1865. *Stock, Joseph S. Showell Green, Spark Hill, near Birmingham.
Stoddart, George.
1864. §STODDART, WILLIAM WALTER, F.G.S., F.C.S. 7 King-square, Bristol.

Year of Election.

1854. ‡Stoess, Le Chevalier, Ch. de W. (Bavarian Consul). Liverpool.
*STOKES, GEORGE GABRIEL, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambrdge. Lensfield Cottage, Lensfield-road, Cambridge.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Astronomer Royal at the Cape of Good Hope. Cape Town.
1859. ‡Stone, Dr. William H. 13 Vigo-street, London, W.
1857. ‡STONEY, BINDON B., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1861. *STONEY, GEORGE JOHNSTONE, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. Weston House, Dundrum, Co. Dublin.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1873. §Storr, William. The 'Times' Office, Printing-house-square, E.C.
1867. ‡STORRAR, JOHN, M.D. Heathview, Hampstead, London, N.W.
1859. §Story, James. 17 Bryanston-square, London, W.
1871. *STRACHEY, Major-General RICHARD, R.E., K.C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. The Rectory House, Clapham Common, London, S.W.
1863. ‡Straker, John. Wellington House, Durham.
1868. ‡STRANGE, Lieut.-Colonel A., F.R.S., F.R.A.S., F.R.G.S. India Stores, Belvedere-road, Lambeth, London, S.E.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
Strickland, William. French-park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1866. *STRUTT, The Hon. ARTHUR, F.G.S. Milford House, Derby.
1872. *Stuart, Edward A. Sudbury-hill, Harrow.
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1873. §Style, George, M.A. Giggleswick School, Yorkshire.
1857. ‡SULLIVAN, WILLIAM K., Ph.D., M.R.I.A. Royal College of Science for Ireland; and 53 Upper Leeson-road, Dublin.
1873. §Sutcliffe, J. W. Sprink Bank, Bradford.
1873. §Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.G.S. Stafford House, London, S.W.
1855. ‡*Sutton, Edwin.*
1863. §SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1861. *Swan, Patrick Don S. Kirkaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. 2 Hope-street, St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke. Forest Hill Lodge, Warsop, Mansfield, Nottinghamshire.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburn, Sir John. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1863. ‡SWINHOE, ROBERT, F.R.G.S. 33 Oakley-square, S.W.; and Oriental Club, London, W.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. †Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London. W.
SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. 60 Maddox-street, W.; and Athenæum Club, London, S.W.

Year of Election.

1870. §SYMES, RICHARD GLASCOTT, F.G.S., Geological Survey of Ireland. 14 Hume-street, Dublin.
1856. *Symonds, Frederick, F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., Sec. M.S. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. §Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. 17 Drummond-place, Edinburgh.
1867. ‡Tait, P. M., F.R.G.S. Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire.
TALBOT, WILLIAM HENRY FOX, M.A., LL.D., F.R.S., F.L.S. Lacock Abbey, near Chippenham.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London, W.
1866. ‡Tarbottom, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1861. *Tarratt, Henry W. Bushbury Lodge, Leamington.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. 2 Queen's-elms, Belfast.
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1865. ‡*Tate, Thomas.*
1858. *Tatham, George. Springfield Mount, Leeds.
1864. *TAWNEY, EDWARD B., F.G.S. 16 Royal York-crescent, Clifton, Bristol.
1871. ‡Tayler, William, F.S.A., F.S.S. 28 Park-street, Grosvenor-square, London, W.
1867. ‡Taylor, Rev. Andrew. Dundee.
Taylor, Frederick. Laurel-cottage, Rainhill, near Prescot, Lancashire.
*Taylor, James. Culverlands, near Reading.
*TAYLOR, JOHN, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, Upper Thames-street, London, E.C.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1873. §Taylor, J. E., F.L.S., F.G.S. The Mount, Ipswich.
Taylor, Captain P. Meadows, in the Service of His Highness the Nizam. Harold Cross, Dublin.
*TAYLOR, RICHARD, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1870. §Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1869. ‡Teesdale, C. S. M. Pennsylvannia, Exeter.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*TENNANT, JAMES, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1859. ‡Thain, Rev. Alexander. New Machar, Aberdeen.

Year of Election.

1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. §THISELTON-DYER, W. T., B.A., B.Sc. 10 Gloucester-road, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1871. §Thomas, Ascanius William Nevill. Chudleigh, Devon.
Thomas, George. Brislington, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1869. §Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
*Thompson, Corden, M.D. 84 Norfolk-street, Sheffield.
1863. ‡Thompson, Rev. Francis. St. Giles's, Durham.
1858. *Thompson, Frederick. South-parade, Wakefield.
1859. §Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Woodlands, Fulshaw, near Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley-hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
1873. §Thompson, M. W. Guiseley, Yorkshire.
THOMPSON, THOMAS. Welton, Brough, Yorkshire.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S., Professor of Anatomy in the University of Glasgow.
1852. ‡Thomson, Gordon A. Bedeque House, Belfast.
Thomson, Guy. Oxford.
1855. ‡Thomson, James. 82 West Nile-street, Glasgow.
1850. *THOMSON, Professor JAMES, M.A., LL.D., C.E. The University, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 276 Eglington-street, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1871. *Thomson, John Millar, F.C.S. King's College, London, W.C.
1863. ‡Thomson, M. 8 Meadow-place, Edinburgh.
1872. §Thomson, Peter. 34 Granville-street, Glasgow.
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.
1865. ‡Thomson, R. W., C.E., F.R.S.E. 3 Moray-place, Edinburgh.
1850. ‡THOMSON, THOMAS, M.D., F.R.S., F.L.S. Hope House, Kew, W.
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in the University of Glasgow. The College, Glasgow.
1871. §Thomson, William Burnes. 11 St. John's-street, Edinburgh.
1870. ‡Thomson, W. C., M.D. 7 Domingo-vale, Everton, Liverpool.
1850. ‡THOMSON, WYVILLE T. C., LL.D., F.R.S., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
1871. ‡Thorburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thorburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1865. *Thornley, S. Gilbertstone House, Bickenhill, near Birmingham.
1866. ‡Thornton, James. Edwalton, Nottingham.
*Thornton, Samuel. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Suffolk Laun, Cheltenham.
1871. §Thorp, Henry. Whalley Range, Manchester.
*THORP, The Venerable THOMAS, B.D., F.G.S., Archdeacon of Bristol. Kemerton, near Tewkesbury.

Year of Election.

1864. *THORP, WILLIAM, jun., B.Sc., F.C.S. 39 Sandringham-road, Kingsland, E.
1871. §THORPE, T. E., Ph.D., F.R.S.E., F.C.S., Professor of Chemistry, Andersonian University, Glasgow. The College, Glasgow.
1868. ‡Thuillier, Colonel. 27 Lower Seymour-street, Portman-square, London, W.
Thurnam, John, M.D. Devizes.
1870. ‡Tichborne, Charles R. S., F.C.S. Apothecaries' Hall of Ireland, Dublin.
1873. *Tiddeman, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1873. §Tilghman, B. C. Philadelphia, United States.
1865. §Timmins, Samuel. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*TINNÉ, JOHN A., F.R.G.S. Briarly, Aigburth, Liverpool.
1861. *TODHUNTER, ISAAC, M.A., F.R.S. Principal Mathematical Lecturer St. John's College, Cambridge. Bourne House, Cambridge.
Todhunter, J. 3 College-green, Dublin.
1857. ‡Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863. ‡Tone, John F. Jesmond-villas, Newcastle-on-Tyne.
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. ‡Tonks, William Henry. 4 Carpenter-road, Edgbaston, Birmingham.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861. *Topham, John. A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.G.S. Geological Survey Office, Jermyn-street, London, S.W.
1863. ‡Torrens, R. R. 2 Gloucester-place, Hyde Park, London, W.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. §Townend, W. H Heaton Hall, Bradford.
1860. ‡Townsend, John. 11 Burlington-street, Bath.
1857. ‡TOWNSEND, REV. RICHARD, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854. ‡TOWSON, JOHN THOMAS, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1859. ‡*Trail, Samuel, D.D., LL.D.*
1870. ‡Traill, William A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1868. ‡TRAQUAIR, RAMSAY H., M.D., Professor of Zoology, Royal College of Science, Dublin.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
Tregelles, Nathaniel. Neath Abbey, Glamorganshire.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
*TREVELYAN, ARTHUR, J.P. Tyneholme, Pencaitland, N.B.
TREVELYAN, Sir WALTER CALVERLEY, Bart., M.A., F.R.S.E. F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.

Year of Election.

1871. §TRIBE, ALFRED, F.C.S. 73 Artesian-road, Bayswater, London, W.
1871. ‡TRIMEN, ROLAND, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. ‡TRISTRAM, Rev. HENRY BAKER, M.A., LL.D., F.R.S., F.L.S. Greatham Hospital, near Stockton-on-Tees.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon
1864. ‡Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Baldwin-street, Bristol.
Tuckett, Frederick. 4 Mortimer-street, Cavendish-square, London, W.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1865. ‡Turbervile, H. Pilton, Barnstaple.
1854. ‡TURNBULL, JAMES, M.D. 86 Rodney-street, Liverpool.
1855. §Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill-villas, Cheltenham.
*TURNBULL, Rev. THOMAS SMITH, M.A., F.R.S., F.G.S., F.R.G.S. Blofield, Norfolk.
1871. §Turnbull, William. 14 Lansdowne-crescent, Edinburgh.
1873. *Turner, George. Horton Grange, Bradford.
Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.
1863. *TURNER, WILLIAM, M.B., F.R.S.E., Professor of Anatomy in the University of Edinbugh. 6 Eton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. 11 Regent's-park-road, London, N.W.
1847. ‡TWISS, Sir TRAVERS, D.C.L., F.R.S., F.R.G.S. 19 Park-lane, London, W.
1865. §TYLOR, EDWARD BURNETT, F.R.S. Linden, Wellington, Somerset.
1858. *TYNDALL, JOHN, LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. (PRESIDENT ELECT.) Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. Seedley-road, Pendleton, near Manchester.

1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1855. ‡Ure, John. 114 Montrose-street, Glasgow.
1859. ‡ *Urquhart, Rev. Alexander.*
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. §Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1873. §Uttley, Hiram. Burnley.

1870. ‡Vale, H. H. 42 Prospect-vale, Fairfield, Liverpool.
*Vallack, Rev. Benjamin W. S. St. Budeaux, near Plymouth.
*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1854. ‡Varley, Cromwell F., F.R.S. Fleetwood House, Beckenham, Kent.
1868. §Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay Avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. 66 Roman-road, Holloway, London, N.
1870. ‡Varley, Mrs. S. A. 66 Roman-road, Holloway, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1863. ‡Vauvert, de Mean A., Vice-Consul for France. Tynemouth.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
1873. *Verney, Edmund H. 16 Queen's-gate-terrace, London, W.

Year of Election.

Verney, Sir Harry, Bart. Lower Claydon, Buckinghamshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1854. *VERNON, GEORGE V., F.R.A.S. 1 Osborne-place, Old Trafford, Manchester.
1854. *Vernon, John. Litherland Park, Litherland, Liverpool.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-cresent, Exeter.
1854. *VIGNOLES, Lieut.-Colonel CHARLES B., C.E., F.R.S., M.R.I.A., F.R.A.S., V.P.I.C.E. 21 Duke-street, Westminster, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1856. ‡VIVIAN, EDWARD, B.A. Woodfield, Torquay.
*VIVIAN, H. HUSSEY, M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1856. §VOELCKER, J. CH. AUGUSTUS, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡Waddington, John. New Dock Works, Leeds.
1870. §WAKE, CHARLES STANILAND. 10 Story-street, Hull.
1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.
1873. §Wales, James. 4 Mount Royd, Manningham, Bradford.
1869. *Walford, Cornelius. 86 Belsize-park-gardens, London, N.W.
1849. §WALKER, CHARLES V., F.R.S., F.R.A.S. Fernside Villa, Redhill, near Reigate.
Walker, Sir Edward S. Berry Hill, Mansfield.
Walker, Frederick John. The Priory, Bathwick, Bath.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1859. ‡ *Walker, James.*
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1842. *Walker, John. Thorncliffe, New Kenilworth-road, Leamington.
1866. *WALKER, J. F., M.A., F.C.P.S., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1869. *Walker, Thomas F. W., M.A., F.R.G.S. 6 Brock-street, Bath.
Walker, William. 47 Northumberland-street, Edinburgh.
1869. ‡Walkey, J. E. C. High-street, Exeter.
Wall, Rev. R. H., M.A. 6 Hume-street, Dublin.
1863. §WALLACE, ALFRED R., F.R.G.S. The Dell, Grays, Essex.
1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 3 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡WALLICH, GEORGE CHARLES, M.D., F.L.S. 60 Holland-road, Kensington, London, W.
Wallinger, Rev. William.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., M.P., F.R.S. Ealing, London, W.
1857. ‡Walsh, Albert Jasper, F.R.C.S.I. 89 Harcourt-street, Dublin.
Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡ *Wanklyn, James Alfred, F.R.S.E., F.C.S.*

Year of Election.

1872. ‡Warburton, Benjamin. Leicester.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida-vale, London, W.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1865. *Warren, Edward P., L.D.S. 13 Old-square, Birmingham.
1869. ‡*Warren, James L.*
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
*WATERHOUSE, JOHN, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1854. ‡Waterhouse Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorn House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
WATSON, HEWETT COTTRELL. Thames Ditton, Surrey.
1873. §Watson, James (Lord Provost). Glasgow.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. §Watson, Thomas Donald. 18A Basinghall-street, London, E.C.
1869. ‡Watt, Robert B. E. Ashby-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1846. §Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1870. §Watts, William. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. §Watts, W. Marshall, D.Sc. Giggleswick Grammar School, near Settle.
1858. ‡Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1862. §WAUGH, Major-General Sir ANDREW SCOTT, R.E., F.R.S., F.R.A.S., F.R.G.S., late Surveyor-General of India, and Superintendent of the Great Trigonometrical Survey. 7 Petersham-terrace, Queen's-gate-gardens, London, W.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
*WAVENEY, Lord, F.R.S. 7 Audley-square, London, W.
*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
*WEBB, Rev. THOMAS WILLIAM, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1859. ‡Webster, John. 42 King-street, Aberdeen.

Year of Election.

1864. §Webster, John. Belvoir-terrace, Sneinton, Nottingham.
1862. ‡Webster, John Henry, M.D. Northampton.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
WEBSTER, THOMAS, M.A., Q.C., F.R.S. 2 Pump-court, Temple, London, E.C.
1845. †Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park, London, N.W.
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1867. §Weldon, Walter. Abbey Lodge, Merton, Surrey.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡*Wesley, William Henry.*
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1873. §West, Samuel H. 6 College-terrace West, London, N.W.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1851. *WESTERN, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.
1870. §Westgarth, William. 3 Brunswick-gardens, Campden-hill, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
Westhead, John. Manchester.
1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1860. §Weston, James Woods. Seedley House, Pendleton, Manchester.
1864. §WESTROPP, W. H. S., M.R.I.A. Lisdoondarna, Co. Clare.
1860. ‡WESTWOOD, JOHN O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1858. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
WHEATSTONE, Sir CHARLES, D.C.L., F.R.S., Hon. M.R.I.A., Professor of Experimental Philosophy in King's College, London. 19 Park-crescent, Regent's Park, London, N.W.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1873. §Whipple, George Matthew, B.Sc., F.R.A.S. The Observatory, Kew.
1853. ‡Whitaker, Charles. Milton Hill, near Hull.
1859. *WHITAKER, WILLIAM, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1864. ‡White, Edmund. Victoria Villa, Batheaston, Bath.
1837. ‡WHITE, JAMES, F.G.S. 14 Chichester-terrace, Kemp Town, Brighton.
1873. §White, John. Medina Docks, Cowes, Isle of Wight.
White, John. 80 Wilson-street, Glasgow.
1859. ‡WHITE, JOHN FORBES. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blandford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1858. ‡Whitehead, J. H. Southsyde, Saddleworth.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Belmont, Rawtenstall, Manchester.

Year of Election.

1855. *Whitehouse, Wildeman W. O. 12 Thurlow-road, Hampstead, London, N.W.

Whitehouse, William. 10 Queen-street, Rhyl.

1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.

*WHITESIDE, JAMES, M.A., LL.D., D.C.L., Lord Chief Justice of Ireland. 2 Mountjoy-square, Dublin.

1866. §Whitfield, Samuel. Golden Hillock, Small Heath, Birmingham.

1852. ‡Whitla, Valentine. Beneden, Belfast.

Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.

1870. §Whittem, James Sibley. Walgrave, near Coventry.

1857. *WHITTY, JOHN IRWINE, M.A., D.C.L., LL.D., C.E. 94 Baggot-street, Dublin.

1863. *Whitwell, Thomas. Thornaby Iron Works, Stockton-on-Tees.

*WHITWORTH, Sir JOSEPH, Bart., LL.D., D.C.L., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.

1870. ‡WHITWORTH, Rev. W. ALLEN, M.A. 185 Islington, Liverpool.

1865. ‡Wiggin, Henry. Metchley Grange, Harbourne, Birmingham.

1860. ‡Wilde, Henry. 2 St. Ann's-place, Manchester.

1852. ‡WILDE, Sir WILLIAM ROBERT, M.D., M.R.I.A. 1 Merrion-square North, Dublin.

1855. ‡Wilkie, John. 24 Blythwood-square, Glasgow.

1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.

1861. *Wilkinson, M. A. Eason-, M.D. Greenheys, Manchester.

1859. §Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.

1873. §Wilkinson, Mrs. Robert Young. Lincoln Lodge, Totteridge, Hertfordshire.

1872. §Wilkinson, William. 168 North-street, Brighton.

1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.

1873. §Willcock, J. W., Q.C. Cleivion, Cemmaes, Montgomeryshire.

*Willert, Paul Ferdinand. Town Hall, Manchester.

1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.

1872. §WILLETT, HENRY. Arnold House, Brighton.

1870. ‡William, G. F. Copley Mount, Springfield, Liverpool.

WILLIAMS, CHARLES JAMES B., M.D., F.R.S. 49 Upper Brook-street, Grosvenor-square, London, W.

1861. *Williams, Charles Theodore, M.A., M.B. 78 Park-street, London, W.

1864. *WILLIAMS, Sir FREDERICK M., Bart., M.P., F.G.S. Goonvrea, Perranarworthal, Cornwall.

1861. *Williams, Harry Samuel, M.A. 49 Upper Brook-street, Grosvenor-square, London, W.

1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.

1871. ‡Williams, James, M.D. The Mount, Malvern.

1870. §WILLIAMS, JOHN. 14 Buckingham-street, London, W.C.

Williams, Robert, M.A. Bridehead, Dorset.

1869. ‡WILLIAMS, Rev. STEPHEN. Stonyhurst College, Whalley, Blackburn.

1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., For. Sec. R.S., F.C.S., Corresponding Member of the French Academy, Professor of Chemistry, and of Practical Chemistry, University College, London. (PRESIDENT.) 23 Fellows-road, Haverstock-hill, London, N.W.

1857. ‡Williamson, Benjamin, M.A. Trinity College, Dublin.

1863. ‡Williamson, John. South Shields.

*Williamson, Rev. William, B.D. Datchworth Rectory, Welwyn, Hertfordshire.

WILLIAMSON, WILLIAM C., F.R.S., Professor of Natural History in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.

Year of Election.

WILLIS, Rev. ROBERT, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 5 Park-terrace, Cambridge.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1857. ‡Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.
1859. *Wills, Alfred. 43 Queen's-gardens, Bayswater, London, W.
1865. ‡Wills, Arthur W. Edgbaston, Birmingham.
WILLS, W. R. Edgbaston, Birmingham.
1859. §Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
Wilson, George. 40 Ardwick-green, Manchester.
1863. ‡Wilson, George. Heron-hill, Hawick.
1861. ‡Wilson, George Daniel. 24 Ardwick-green, Manchester.
1855. ‡Wilson, Hugh. 75 Glassford-street, Glasgow.
1857. ‡Wilson, James Moncrieff. Queen Insurance Company, Liverpool.
1865. §WILSON, JAMES M., M.A. Hillmorton-road, Rugby.
1858. *Wilson, John. Seacroft Hall, near Leeds.
*Wilson, John. 32 Bootham, York.
WILSON, Professor JOHN, F.G.S., F.R.S.E. The University, Edinburgh.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
*Wilson, Thomas, M.A. 3 Hilary-place, Leeds.
1863. *Wilson, Thomas. Shotley Hall, Shotley Bridge, Northumberland.
1861. ‡Wilson, Thomas Bright. 24 Ardwick-green, Manchester.
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1870. ‡Wilson, William Henry. 31 Grove-park, Liverpool.
1847. *Wilson, William Parkinson, M.A., Professor of Pure and Applied Mathematics in the University of Melbourne.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S. 25 Granville-park, Lewisham, London, S.E.
1866. *Windley, W. Mapperley Plains, Nottingham.
*Winsor, F. A. 60 Lincoln's-Inn-fields, London, W.C.
1868. ‡Winter, C. J. W. 22 Bethel-street, Norwich.
1872. ‡*Winter, G. K.*
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
*WOLLASTON, THOMAS VERNON, M.A., F.L.S. 1 Barnepark-terrace, Teignmouth.
1863. *Wood, Collingwood L. Howlish Hall, Bishop Auckland.
1871. ‡Wood, C. H. Devonshire-road, Holloway.
1863. ‡WOOD, EDWARD, J.P., F.G.S. Richmond, Yorkshire.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1861. *Wood, George B., M.D. 1117 Arch-street, Philadelphia, United States.
1870. *Wood, George S. 20 Lord-street, Liverpool.
1856. *WOOD, Rev. H. H., M.A., F.G.S. Holwell Rectory, Sherborne, Dorset.
*Wood, John. The Mount, York.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1861. §Wood, Samuel, F.S.A. St. Mary's Court, Shrewsbury.
1871. ‡Wood, Provost T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
Wood, William. Edge-lane, Liverpool.
1865. *Wood, William, M.D. 99 Harley-street, London, W.

Year of Election.

1872. §Wood, W. R. Carlisle-road, Brighton.
1861. ‡Wood, William Rayner. Singleton Lodge, near Manchester.
*Wood, Rev. William Spicer, M.A., D.D. Oakham, Rutlandshire.
1863. *WOODALL, Major JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1870. ‡Woodburn, Thomas. Rock Ferry, Liverpool.
1850. *Woodd, Charles H. L., F.G.S. Roslyn, Hampstead, London, N.W.
1865. ‡Woodhill, J. C. Pakenham House, Edgbaston, Charlotte-road, Birmingham.
1866. *Woodhouse, John Thomas, C.E., F.G.S. Midland-road, Derby.
1871. §Woodiwis, James. 51 Back George-street, Manchester.
1872. §Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. §Woodman, William Robert, M.D. Alphington-road, Exeter.
*WOODS, EDWARD. 3 Story's-gate, Westminster, London, S.W.
WOODS, SAMUEL. 3 Copthall-buildings, Angel-court, London, E.C.
1869. *Woodward, C. J. 4 Warwick-place, Francis-road, Edgbaston, Birmingham.
1866. §WOODWARD, HENRY, F.R.S., F.G.S. British Museum, London, W.C.
1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
Woolgar, J. W., F.R.A.S. Lewes, Sussex.
Woolley, John. Staleybridge, Manchester.
1856. §Woolley, Thomas Smith, jun. South Collingham, Newark.
1872. ‡Woolmer, Shirley. 6 Park-crescent, Brighton.
Worcester, The Right Rev. Henry Philpott, D.D., Lord Bishop of Worcester.
1863. *Worsley, Philip J. 1 Codrington-place, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Old Meeting Parsonage, Mansfield.
Worthington, Archibald. Whitchurch, Salop.
Worthington, James. Sale Hall, Ashton-on-Mersey.
Worthington, William. Brockhurst Hall, Northwich, Cheshire.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1871. §WRIGHT, C. R. A., D.Sc., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1857. ‡Wright, Edward, LL.D. 23 The Boltons, West Brompton, London, S.W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. ‡WRIGHT, E. PERCEVAL, A.M., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1866. ‡Wright, G. H. Heanor Hall, near Derby.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
*Wright, Robert Francis. Hinton Blewett, Temple-Cloud, near Bristol.
1855. ‡WRIGHT, THOMAS, F.S.A. 14 Sydney-street, Brompton, London, S.W.
Wright, T. G., M.D. Milnes House, Wakefield.
1865. ‡Wrightson, Francis, Ph.D. Ivy House, Kingsnorton.
1871. §Wrightson, Thomson. Norton Hall, Stockton-on-Tees.
1867. ‡Wünsch, Edward Alfred. 3 Eaton-terrace, Hillhead, Glasgow.
1866. §WYATT, JAMES, F.G.S. Peter's Green, Bedford.
Wyld, James, F.R.G.S. Charing Cross, London, W.C.
1863. *Wyley, Andrew. 21 Barker-street, Handsworth, Birmingham.
1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.

Year of Election.

1871. §Wynn, Mrs. William. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S., of the Geological Survey of India. Bombay.

*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
Yates, James. Carr House, Rotherham, Yorkshire.
1867. ‡Yeaman, James. Dundee.
1855. ‡Yeats, John, LL.D., F.R.G.S. Clayton-place, Peckham, London, S.E.
*YORKE, Colonel PHILLIP, F.R.S., F.R.G.S. 89 Eaton-place, Belgrave-square, London, S.W.
1870. *YOUNG, JAMES, F.R.S, F.C.S. Kelly, Wemyss Bay, by Greenock.
Young, John. Taunton, Somersetshire.
Young, John. Hope Villa, Woodhouse-lane, Leeds.
Younge, Robert, F.L.S. Greystones, near Sheffield.
*Younge, Robert, M.D. Greystones, near Sheffield.
1868. †Youngs, John. Richmond Hill, Norwich.
1871. ‡YULE, Colonel HENRY, C.B. East India United Service Club, St. James's-square, London, S.W.

CORRESPONDING MEMBERS.

Year of
Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1857. M. Antoine d'Abbadie.
1868. M. D'Avesac, Mem de l'Institut de France. 42 Rue du Bac, Paris.
1866. Captain I. Belavenetz, R.I.N., F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt, Russia.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1872. Ch. Bergeron, C.E. Lausanne, Switzerland.
1861. Dr. Bergsma, Director of the Magnetic Survey of the Indian Archipelago. Utrecht, Holland.
1857. Professor Dr. T. Bolzani. Kasan, Russia.
1846. M. Boutigny (d'Evreux). Paris.
1868. Professor Broca. Paris.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological Institute of the Netherlands. Utrecht, Holland.
1861. Dr. Carus. Leipzig.
1864. M. Des Cloizeaux. Paris.
1871. Professor Dr. Colding. Copenhagen.
1873. Signore Guido Cora.
1870. J. M. Crafts, M.D.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1872. Professor M. Croullebois. 18 Rue Sorbonne, Paris.
1866. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1872. Professor G. Devalque. Liège, Belgium.
1870. Dr. Anton Dohrn. Naples. [Berlin.
1845. Heinrich Dove, Professor of Natural Philosophy in the University of
Professor Dumas. Paris.
Professor Christian Gottfried Ehrenberg, M.D., Secretary of the Royal Academy, Berlin.
1846. Dr. Eisenlohr. Carlsruhe, Baden.
1842. Prof. A. Erman. 122 Friedrichstrasse, Berlin.
1848. Professor Esmark. Christiania.
1861. Professor A. Favre. Geneva.
1872. W. de Fonvielle. Rue des Abbesse, Paris.
1856. Professor E. Frémy. Paris.
1842. M. Frisiani.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1872. Professor Paul Gervais. Museum de Paris.
1870. Govenor Gilpin. Colorado, United States.
1852. Professor Asa Gray. Cambridge, U.S.
1866. Professor Edward Grube, Ph.D.
1871. Dr. Paul Güssfeldt of the University of Bonn. 33 Meckenheimer-street, Bonn, Prussia.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1872. Professor James Hall. Albany, State of New York.
1864. M. Hébert, Professor of Geology in the Sorbonne, Paris.
Professor Henry. Washington, U.S.
1868. A. Heynsius. Leyden.

Year of Election.

1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington.
1861. Dr. Hochstetter. Vienna.
1842. M. Jacobi, Member of the Imperial Academy of St. Petersburg.
1867. Janssen, Dr. 21 Rue Labat (18° Arrondissement), Paris.
1862. Charles Jessen, Med. et Phil. Dr., Professor of Botany in the University of Greifswald, and Lecturer of Natural History and Librarian at the Royal Agricultural Academy, Eldena, Prussia.
1862. Aug. Kekulé, Professor of Chemistry. Ghent, Belgium.
1866. Dr. Henry Kiepert, Professor of Geography. Berlin.
1861. M. Khanikof. 11 Rue de Condé, Paris.
1873. Dr. Felix Klein, Erlangen, Bavaria.
1868. Professor Karl Koch. Berlin.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
1856. Laurent-Guillaume De Koninck, M.D., Professor of Chemistry and Palæontology in the University of Liége, Belgium.
Dr. Lamont. Munich.
1872. Georges Lemoine. 19 Rue du Sommerard, Paris.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1857. Professor Elias Loomis. Yale College, New Haven, United States.
1871. Professor Jacob Luroth. Carlsruthe, Baden.
1871. Dr. Lutken. Copenhagen.
1869. Professor C. S. Lyman. Yale College, New Haven, United States.
1867. Professor Mannheim. Paris.
1867. Professor Ch. Martins, Director of the Jardin des Plants. Montpellier, France.
1862. Professor P. Merian. Bâle, Switzerland.
1846. Professor von Middendorff.
1848. Professor J. Milne-Edwards. Paris.
1855. M. l'Abbé Moigno. Paris.
1864. Dr. Arnold Moritz. Tiflis, Russia.
1856. Edouard Morren, Professeur de Botanique à l'Université de Liége, Belgium.
1866. Chevalier C. Negri, President of the Italian Geographical Society, Florence, Italy.
1864. Herr Neumayer. The Admiralty, Leipzirger Platz, 12, Berlin.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1848. Professor Nilsson. Lund, Sweden.
1856. M. E. Peligot, Memb. de l'Institut, Paris.
1861. Professor Benjamin Pierce. Washington, U.S.
1857. Gustav Plarr. Strasburg.
1870. Professor Felix Plateau. Place du Casino, 15, Gand, Belgium.
1868. Professor L. Radlkofer. Professor of Botany in the University of Munich.
1872. Professor Victor von Richter.
1873. Baron von Richthofen, Berlin.
M. De la Rive. Geneva.
1866. F. Roemer, Ph D., Professor of Geology and Palæontology in the University of Breslau. Breslau, Prussia.
1850. Professor W. B. Rogers. Boston, U.S.
1857. Baron Herman de Schlagintweit-Sakünlünski. Jaegersburg Castle, near Forchheim, Bavaria.
1857. Professor Robert Schlagintweit. Giessen.
1868. Padre Secchi, Director of the Observatory at Rome.
1872. Professor Carl Semper. Wurtemburg, Bavaria.
1873. Dr. A. Shafarik. Prague.
1861. M. Werner Siemens. Berlin.
1849. Dr. Siljestrom. Stockholm.
1873. Professor J. Lawrence Smith. Louisville, U.S.

Year of Election.

1862. J. A. de Souza, Professor of Physics in the University of Coimbra, Portugal.
1864. Adolph Steen, Professor of Mathematics, Copenhagen.
1866. Professor Steenstrup. Copenhagen.
1845. Dr. Svanberg. Stockholm.
1871. Dr. Joseph Szabo. Pesth, Hungary.
1870. Professor Tchebichef. Membre de l'Academie de St. Petersburg.
1852. M. Pierre de Tchihatchef, Corresponding Member of the Institut de France. 1 Piazza degli Zuaai, Florence.
1864. Dr. Otto Torell. Prof. of Geology in the University of Lund, Sweden.
1864. Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1861. M. de Verneuil. Paris.
1848. M. Le Verrier. Paris.
1868. Professor Vogt. Geneva.
Baron Sartorius von Waltershausen. Göttingen, Hanover.
1842. Professor Wartmann. Geneva.
1868. Dr. H. A. Weddell. Poitiers, France.
1864. Dr. Frederick Welwitsch.
1872. Professor A. Wurtz. Paris.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Admiralty, Library of.
Arts, Society of.
Asiatic Society (Royal).
Astronomical Society (Royal).
Belfast, Queen's College.
Birmingham, Institute of Mechanical Engineers.
—— Midland Institute.
Bristol Philosophical Institution.
Cambridge Philosophical Society.
Cornwall, Royal Geological Society of.
Dublin Geological Society.
——, Royal Irish Academy.
——, Royal Society of.
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